

DISSERTATION REPORT
ON
ASSESSMENT OF GROUNDWATER
RESOURCE IN COASTAL REGIONS OF
ANDHRA PRADESH

SUBMITTED
BY

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SUBMITTED IN:- MAY, 2017

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled "ASSESSMENT OF GROUNDWATER RESOURCES IN COASTAL REGIONS OF ANDHRA PRADESH" in partial fulfilment of the requirements for the award of degree of MASTER OF SCIENCE in ENVIRONMENTAL SCIENCES submitted in the CENTRE FOR ENVIRONMENTAL SCIENCES, CENTRAL UNIVERSITY OF JHARKHAND, is an authentic record of my own work carried out during the period from January, 2017 to May, 2017 under the supervision of Dr. Purabi Saikia and Dr. M.S. Rao.

The matter embodied in this dissertation has not been submitted by me for the award of my other degree.

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This dissertation entitled “Assessment of groundwater resources in the coastal regions of Andhra Pradesh” submitted by Miss Sakshi Sri, Centre for Environmental Sciences, Central University of Jharkhand, Ranchi as a part of the Master programme, is an original work and has not been submitted so far in part or in full, for any other degree or diploma of any University or Institution.

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ABSTRACT:

Water is essential for life and is always the talk of the town either due to too much of it or too little of it. Groundwater is a regenerated phenomenon. It is simply the existed water in vents and scratches in rocks beneath the earth surface. As groundwater is being positioned below the surface of earth at its saturation level and that is acknowledged as aquifers, within which water quench the crevices and openings of rocks and residues. Groundwater is the highly treasurable asset of any nation. It helps sustaining life and promote developmental activities. In India, groundwater fulfils almost 85% of rural domestic needs and 50% of urban needs .In today's world the rate of contamination has exceeded its limits and the after affect has seen in the form of surface water contamination. As groundwater and surface water are interdependent on each other for example- contaminated aquifers that discharges continuous groundwater to streams can result in long-term contamination of surface water; conversely, streams can be a major source of contamination of aquifers.

The area of concern is Andhra Pradesh which is separated from Telangana in the year 2014, because of separation the coastline importance has increased. It has a coastline of about 974 km. The purpose of this study to examine the salt water intrusion presence in the coastal districts and if presence is their then in which amount salinity is there, these presence are examined by isotopic and ionic analysis.

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CHAPTER - 1

1.1. IMPORTANCE OF THE STUDY OF GROUNDWATER RESOURCES IN COASTAL ZONE:

Water sources exist in nature in many of its forms like of rivers, lakes, glaciers, rain water, groundwater, atmospheric moisture etc. Groundwater is simply the existed water in vents and scratches in rocks beneath the earth's surface. It is created from the collectively from rainfall, melting of ice and snow. Through the soil water moves as sub- surface moisture into groundwater system stored in aquifers and when it find its way to surface it gets discharged from ground to lakes, streams or oceans.

Groundwater is a regenerated phenomenon and dynamic in nature. It is over used by factors such as, the expansion of urbanization, industrialisation and irrigation activities. Hence conservation and proper monitoring is mandatory. There conservation is mandatory as because of the condition of increasing demands and decreasing the available resources. As ground water plays an important role in sustaining India's economy, environment, and standard of living, it is not only the main source for water supply in urban areas for domestic uses, but also in the largest and most productive source of irrigation water. Fresh groundwater resources management in coastal aquifers is a very sensitive issue for developed and developing nations. India has a dynamic coast line of about 7500 km length, including the main coast line of about 5400km, and that of which Andhra Pradesh has coastline of 974km.

As per the CGWB report-2014 about 25 percent of the total population of India resides in the coastal tracts of the country. The coastal zone is under increasing stress due to development of industries, trade and commerce, tourism and resultant human population growth and migration resulting deterioration of natural resources. Another important worsening factor for depletion of groundwater is urbanization, since most of the urban centres are located along the coast, in turn consumption of water resource along the coastal zones. As population and demand rises, groundwater resources are increasingly prone to overuse and contamination. Seawater intrusion is one of the most common forms of groundwater contamination in coastal aquifers.

Seawater intrusion occurs in coastal and deltaic regions all over the world, where population density is high and many human activities takes place. Coastal zone faces many hydrogeological problems due to over exploitation of water resources; the most common is the seawater intrusion into coastal aquifers. The overuse of groundwater along the coastal belts for various purposes has affected ground water quality and quantity. It has led to rapid decline in groundwater levels leading to seawater intrusions and water quality deterioration.

In this report, the study is focussed on the coastal zone of Andhra Pradesh. And through various isotopic and chemical parameters it is investigated that the coastal area is containing salt amount or not and if present then it is due to evaporation, sea water up coning or by some other means.

This all will be examined step by step in the upcoming chapters.

This chapter includes the basic information about groundwater and their importance and how it is related with hydrological cycle and after the rain, the infiltration process and the medium through it passes (zone of aeration and saturation). And basic properties of rock through which it passes and goes into the aquifer and the applied physics that is applied is used in the chapter. And about the idea of salt water intrusion and their mechanism and the literature review that is being done regarding the salt water intrusion.

1.2. INTRODUCTION OF GROUNDWATER:

Groundwater is the water that occurs beneath the surface of Earth, where it occupies all or part of the void spaces in soils or geologic strata. It is also called subsurface water to distinguish it from surface water, which is found in large bodies like the oceans or lakes or which flows overland in streams. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Groundwater is recharged from, and eventually flows to, the surface naturally; natural discharge often occurs at springs and seeps, and can form oases or wetlands both surface and subsurface water are related through hydrological cycle (the continuous circulation of water in the Earth-atmosphere system).

Ocean contains about 97% of the liquid water present in the Earth, rest 3% is freshwater present inland. Groundwater contributes about 1% of the water on the Earth. It contributes to 35 times the amount of water in lakes and streams.

1.3. GROUNDWATER AND HYDROLOGIC CYCLE:

The hydrological cycle is the most elemental principle of hydrology. Water evaporates (**Fig.1.1.**) and travels into the air and becomes part of a cloud. It falls down to earth as precipitation. Part of it evaporates again. This happens repeatedly in a never-ending cycle. This hydrologic cycle never stops. Water keeps moving and changing from a solid to liquid to gas, from time to time. Precipitation creates runoff that travels over the ground surface and helps to fill lakes and rivers. It also percolates or moves downward through openings in the soil and rock to replenish aquifers under the ground. Some places receive more precipitation than others do with an overall balance. These areas are usually close to oceans or large bodies of water that allow more water to evaporate and form clouds, other areas receive less as compared to them. Often these areas are far from seawater or near mountains. As clouds move up and over mountains, the water vapour condenses to form precipitation and freezes. The following describes and represents hydrological cycle.

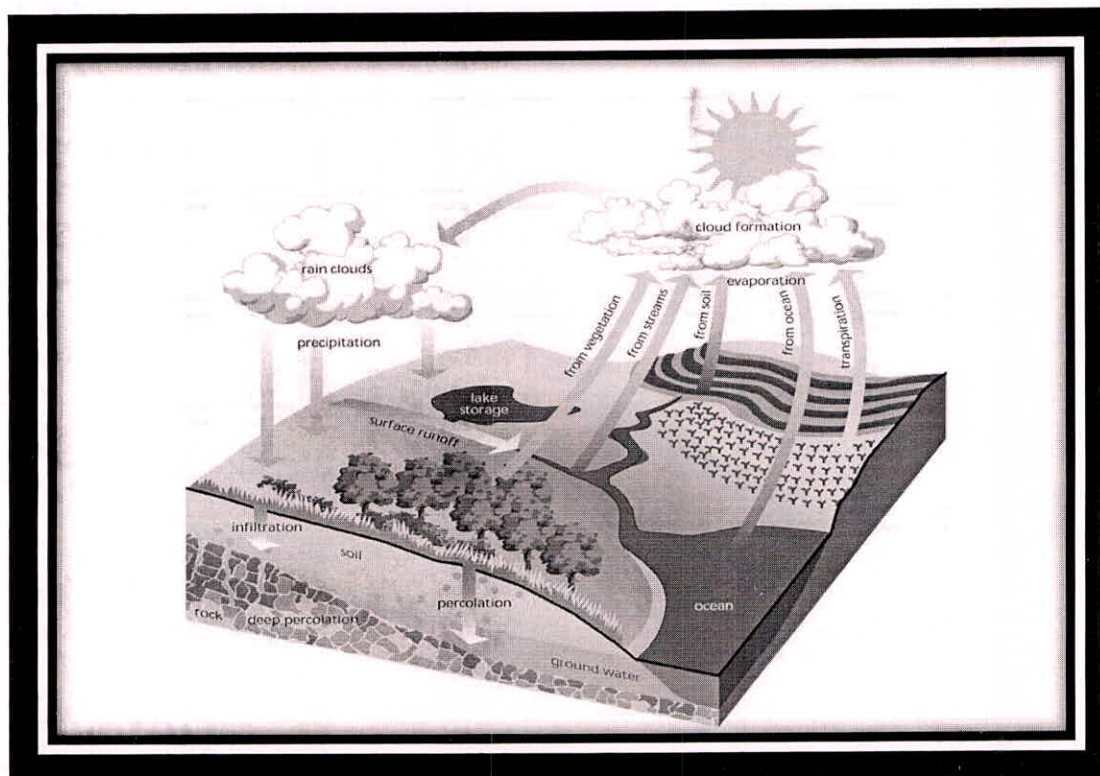


Figure.1.1. Processes in hydrological cycle.

Source: conserve energy under hydrological cycle.

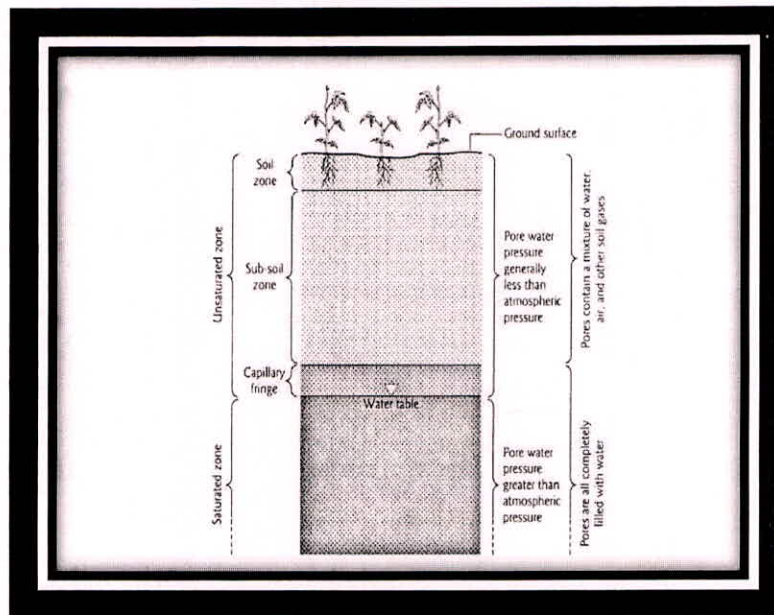
1.4 VERTICAL DISTRIBUTION OF GROUNDWATER:

The subsurface occupies of groundwater is divided into zones of aeration and saturation. The zone of aeration consists of interstices occupied partially by water and partially by air. In the zone of saturation all interstices are filled with water, under hydrostatic pressure. Here, sub-soil surface water gives the summation of soil moisture moisture of unsaturated zone and the saturated zone. (Fig.1.2).

The zone or aeration contains vadose water. The zone of aeration may be further divided into soil water zone, intermediate vadose zone and capillary fringe. Soil water zone is the one, nearest to the ground surface. It is the zone where plants and trees on the surface get their moisture. The intermediate vadose zone is also known as sub soil zone. This has a bit more

moisture than air content. Below the subsoil zone lies the capillary fringe. In the capillary fringe, groundwater rise up due to capillary action which is possible due to the property of surface tension of water. In that level pore spaces are very low and thus water rises up to a certain height. In the zone of aeration, pore pressure is generally less than atmospheric pressure.

The saturated zone extends from the upper surface of saturation down to underlying



impermeable rock. In the absence of overlying impermeable strata, the water table, or phreatic

Figure 1.2. The figure depicts information about the zone beneath the earth surface where saturated and unsaturated zones are present. [Source: geology and water by (Wayne)].

Surface, forms the upper surface of the zone of saturation. This is defined as the surface of atmospheric pressure and appears as the level at which water stands in a well penetrating the aquifer. Actually, saturation extends slightly above the water table due to capillary attraction; however, water is held here at less than atmospheric pressure. Water occurring in the zone of saturation is commonly referred to simply as groundwater, but the term phreatic water is also employed.

1.5. TYPES OF WATER BEARING FORMATIONS:

Water bearing formations are defined as those formations which have sufficient amount of pore spaces which help in storing water. These formations also help in migration and movement of water particles through them due to the presence of inter-connected pore spaces. Such a property in a formation is called permeability. The measure of amount of pore spaces in a formation is called porosity. Various types of water bearing formations include:

1. Aquifer 2. Aquitard 3. Aquiclude 4. Aquifuge

1.5.1 AQUIFER-

An aquifer is an underground layer of water-bearing permeable rock or unconsolidated materials (gravel, sand, or silt) from which groundwater can be extracted using a water well. The study of water flow in aquifers and the characterization of aquifers is called hydrogeology. An aquifer is a ground-water reservoir composed of geologic units that are saturated with water and sufficiently permeable to yield water in a usable quantity to wells and springs. Sand and gravel deposits, sandstone, limestone, and fractured, crystalline rocks are examples of geological units that form aquifers. Aquifers provide two important functions:

- It transmit ground water from areas of recharge to areas of discharge.
- It provides a storage medium for usable quantities of ground water.

1.5.1.1 TYPES OF AQUIFERS-

Depending upon the overlying and underlying rocks, aquifers can be classified as confined or unconfined. A leaky aquifer is a combination of both of the above types.

1.5.1.1.1. Unconfined Aquifer-

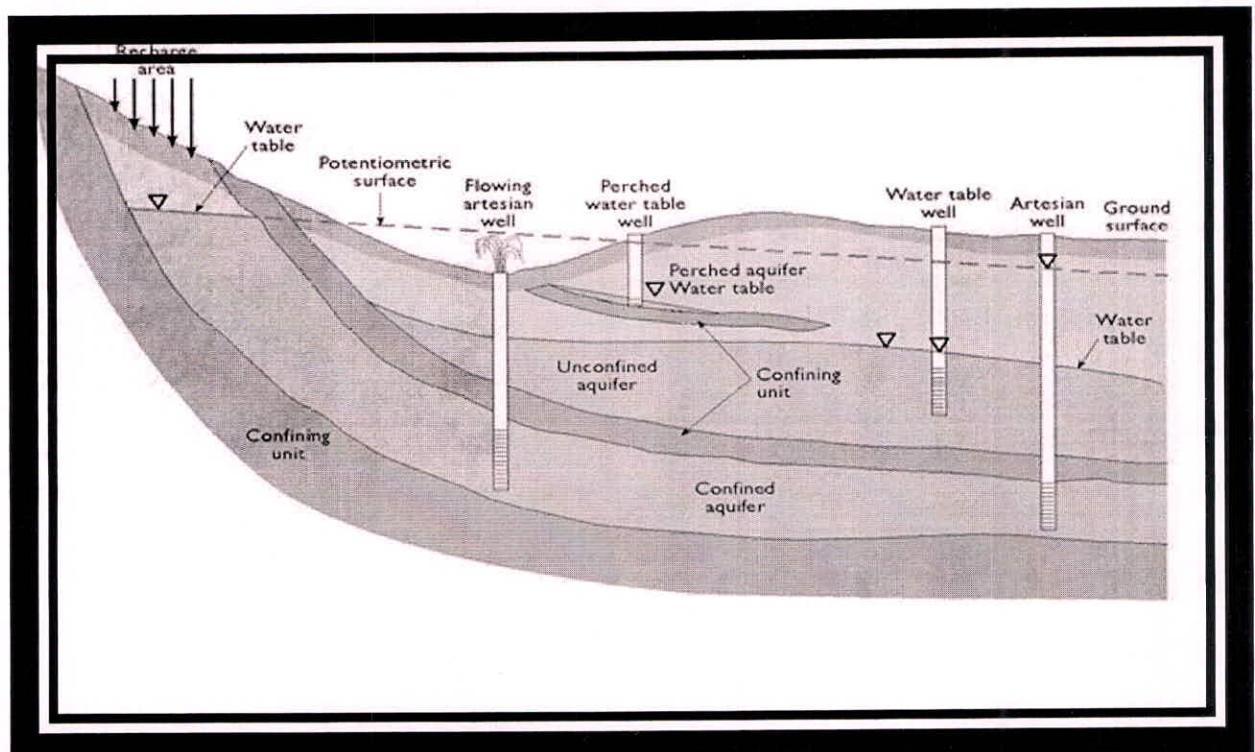
An unconfined aquifer is one in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pumping from wells, and permeability. Rises

and falls in the water table correspond to changes in the volume of water in storage within an aquifer. The upper aquifer in (Fig1.3) is also unconfined. Contour maps and profiles of the water table can be prepared from elevations of water in wells that tap the aquifer to determine the quantities of water available and their distribution and movement. A special case of an unconfined aquifer involves perched water bodies, as illustrated by (Fig1.3). This occurs wherever a groundwater body is separated from the main groundwater by a relatively impermeable stratum of small areal extent and by the zone of aeration above the main body of groundwater. Clay lenses in sedimentary deposits often have shallow perched water bodies overlying them. Wells tapping these sources yield only temporary or small quantities of water.

1.5.1.1.2 Confined Aquifer-

Confined aquifers, also known as artesian or pressure aquifers, occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. In a well penetrating such an aquifer, the water level will rise above the bottom of the confining bed, as shown by the artesian and flowing wells of (fig.1.3). Water enters a confined aquifer in an area where the confining bed rises to the surface; where the confining bed ends underground, the aquifer becomes unconfined. A region supplying water to a confined area is known as a recharge area; water may also enter by leakage through a confining bed. Rises and falls of water in wells penetrating confined aquifers result primarily from changes in pressure rather than changes in storage volumes. Hence, confined aquifers display only small changes in storage and serve primarily as conduits for conveying water from recharge areas to locations of natural or artificial discharge.

Figure .1.3. The figure depicts the overall mechanism of groundwater from



potentiometric surface to the area which is confined or unconfined.

Source: Colorado geological society.

1.5.2. AQUITARD –

An aquitard is a partly permeable geologic formation. It transmits water at such a slow rate that the yield is insufficient. Pumping by wells is not possible. For example, sand lenses in a clay formation will form an aquitard.

1.5.3. AQUICLUDE-

An aquiclude is composed of rock or sediment that acts as a barrier to groundwater flow. Aquicludes are made up of low porosity and low permeability rock/sediment such as shale or clay. Aquicludes have normally good storage capacity but low transmitting capacity.

1.5.4. AQUIFUGE-

An aquifuge is a geologic formation which doesn't have interconnected pores. It is neither porous nor permeable. Thus, it can neither store water nor transmit it. Examples of aquifuge are rocks like basalt, granite, etc. without fissures.

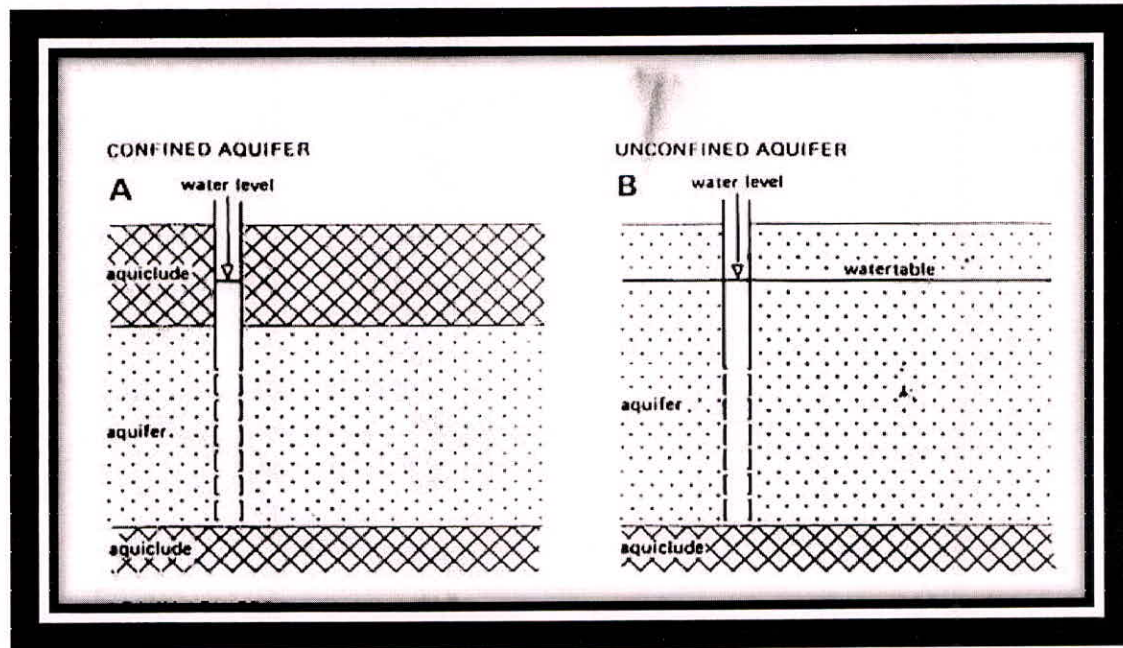


Figure 1.4. The figure shows the confined and unconfined aquifers.

Source: 2002,Fitts (GW).

1.6. MOVEMENT OF GROUNDWATER:

On the surface, movement of water seems quite a simple phenomenon, where water flows under the action of gravity. However, under the surface, the movement is quite complex. As water travels through the interstices of the rocks number of factors come to play. The basic principle says that as surface water moves from a point of higher elevation to that of lower elevation, subsurface water travels from points of higher hydraulic head to those of lower hydraulic head. Hydraulic head is nothing but the specific measurement of liquid pressure above a geodetic datum. So basically we can say that water moves from a point of higher pressure to a point of lower pressure.

Various rock properties which affect the movement of groundwater are as:

1. Porosity.
2. Specific Yield.
3. Specific Retention.
4. Coefficient of permeability.
5. Transmissibility.
6. Specific Storage.
7. Storage Coefficient.

1.6.1. POROSITY-

Porosity is represented by 'n' and is mainly the percentage of voids. The larger the pore space or the greater their number, the higher the porosity and the larger the water-holding

$$n = \frac{V_v}{V} \times 100\%$$

Where,

n is the porosity (percentage)

V_v is the volume of void space in a unit volume of earth materials (L^3 , cm^3 or m^3)

V is the unit volume of earth material, including both voids and solids (L^3 , cm^3 or m^3)

capacity. It is defined mathematically by the equation,

In sediments or sedimentary rocks the porosity depends on grain size, the shape of the grains, the degree of sorting and the degree of cementation. In rocks, the porosity depends upon the extent, spacing and pattern of cracks and fractures.

The porosity of well-rounded sediments, which have been sorted so that they are all about the same size, is independent of particle size, depending upon the packing. Well-rounded coarse-grained sediments usually have higher porosity than fine-grained sediments, because the grains do not fit together well (**Fig. 1.5**).

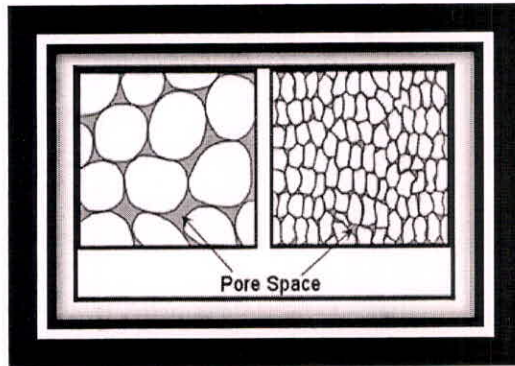


Figure 1.5. This figure showing the grain size and distribution can affect porosity of rocks, coarse grained shaped have high porosity than fine grained.

Source: Drilling formulas.com(geology).

In igneous and metamorphic rocks porosity is usually low because the minerals tend to be inter grown, leaving little free space. Higher fractured igneous and metamorphic rocks however, could have high secondary porosity. Since cements tend to fill in the pore space, highly cemented sedimentary rocks have lower porosity. Poorly sorted sediments (sediments contains a mixture of grain sizes) usually have lower porosity because the fine-grained fragments tend to fill the open spaces. The porosity of sediments is affected by the shape of the grains. Well-rounded grains may be almost perfect spheres, but many grains are very irregular. They can be shaped like rods, disks, or books. Sphere-shaped grains will pack more tightly and have less porosity than particles of other shapes. The fabric or orientation of the particles, if they are not spheres, also influences porosity.

1.6.2. SPECIFIC YIELD-

Specific yield (S_y) is the ratio of the volume of water that drains from a saturated rock owing to the attraction of gravity (or by pumping from wells) to the total volume of the saturated aquifer. It is defined mathematically by the equation:

$$S_y = \frac{V_w}{V} \times 100\%$$

where,

V_w is the volume of water in a unit volume of earth materials (L^3 , cm^3 or m^3)

V is the unit volume of earth material, including both voids and solids (L^3 , cm^3 or m^3)

1.6.3. SPECIFIC RETENTION-

Specific retention (S_r) is the ratio of the volume of water that cannot be drained out to the total volume of the saturated aquifer. Since the specific yield represents the volume of water that a rock will yield by gravity drainage, hence the specific retention is the remainder. The sum of the two equal's porosity.

$$n = S_r + S_y$$

1.6.4. COEFFICIENT OF PERMEABILITY-

Permeability is the ease with which water can flow in a soil mass or a rock. The coefficient of permeability (K) is equal to the discharge (m^3/s) per unit area (m^2) of soil mass under unit hydraulic gradient. Because the discharge per unit area equals to the velocity, the coefficient of permeability has the dimension of the velocity [L/T]. It is usually expressed as cm/s , m/s , m/day , etc. The coefficient of permeability is also called hydraulic conductivity.

1.6.5. TRANSMISSIVITY-

Transmissivity (T) is the discharge rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.

$$T = Kb \text{ (confined aquifer)}$$

$$T = Kh \text{ (unconfined aquifer)}$$

Where, 'b' is the saturated thickness of the aquifer. 'b' is equal to the depth of a confined aquifer. It is equal to the average thickness of the saturated zone of an unconfined aquifer.

1.6.6. SPECIFIC STORAGE-

Specific Storage (SS) is the amount of water per unit volume of a saturated formation that is stored or expelled from storage owing to compressibility of the mineral skeleton and the pore water per unit change in head. This is also called the elastic storage coefficient. The concept can be applied to both aquifers and confining units. The specific storage is given by the expression (Jacob 1940, 1950; cooper 1966):

$$S_s = \rho_w g (\alpha + n\beta)$$

where	ρ_w	is the density of the water (M/L ³ ; Kg/m ³)
	g	is the acceleration of gravity (L/T ² ; m/s ²)
	α	is the compressibility of the aquifer skeleton (1/(M/LT ²); m ² /N)
	n	is the porosity
	β	is the compressibility of water (1/(M/LT ²); m ² /N)

1.6.7. STORAGE COEFFICIENT-

Storage coefficient (S) is the volume of water released from storage, or taken into storage, per unit of aquifer storage area per unit change in head. The storage coefficient is also called **Storativity**. The storage coefficient is a dimensionless as it is the ratio of the volume of water released from original unit volume. The water-yielding capacity of an aquifer can be expressed in terms of its storage coefficient. In unconfined aquifers, Storativity is the same as the specific yield of the aquifer. In confined aquifer, Storativity is the result of compression of the aquifer and expansion of the confined water when the head (pressure) is reduced during pumping. Ground water in its natural state is invariably moving.

Material	$K(\text{cm/sec})$	Source
Gravel	10^{-1} to 100	1
Clean sand	10^{-4} to 1	1
Silty sand	10^{-5} to 10^{-1}	1
Silt	10^{-7} to 10^{-3}	1
Glacial till	10^{-10} to 10^{-4}	1
Clay	10^{-10} to 10^{-6}	1,2
Limestone and dolomite	10^{-7} to 1	1
Fractured basalt	10^{-5} to 1	1
Sandstone	10^{-8} to 10^{-3}	1
Igneous and metamorphic rock	10^{-11} to 10^{-2}	1
Shale	10^{-14} to 10^{-8}	2

Figure1.1. The following table lists some typical ranges of hydraulic conductivity values for common rocks and soils. These ranges are mostly based on data compiled by Davis (1969) and summarized by Freeze and Cherry (1979).

1.7. COASTAL HYDROLOGY:

Coastal zones contain some of the most densely populated areas in the world as they generally present the best conditions for productivity. This created more pressure on coastal resources, which necessitates rational utilization of land and water in coastal region. Groundwater is the major irrigation source for coastal agriculture besides its domestic utility. The availability of groundwater depends mainly on rainfall and recharge from freshwater sources viz., river and canal. The demand for fresh water is increasing drastically over the years and groundwater is being exploited beyond its renewable capability. This extensive exploitation lower downs the groundwater level resulting in seawater intrusion and associated freshwater crisis in coastal region.

1.8. GROUNDWATER PROCESSES IN COASTAL REGION:

The remarkable processes that occur in coastal regions are salt water intrusion and submarine groundwater discharge. Both of them plays a significant role which affects lifestyle of people in coastal zones.

1.8.1. SEA WATER INTRUSION:

Sea water intrusion, or encroachment, is defined by Freeze and Cherry (1979) as the migration of salt water into fresh water aquifers under the influence of groundwater development. Sea water intrusion is the encroachment of sea water into fresh water aquifers due to natural processes or human activities. Sea water intrusion is caused by decreases in groundwater levels or by rises in seawater levels. While over pumping of groundwater is the primary cause of sea water intrusion, other factors have less contribution to the problem.

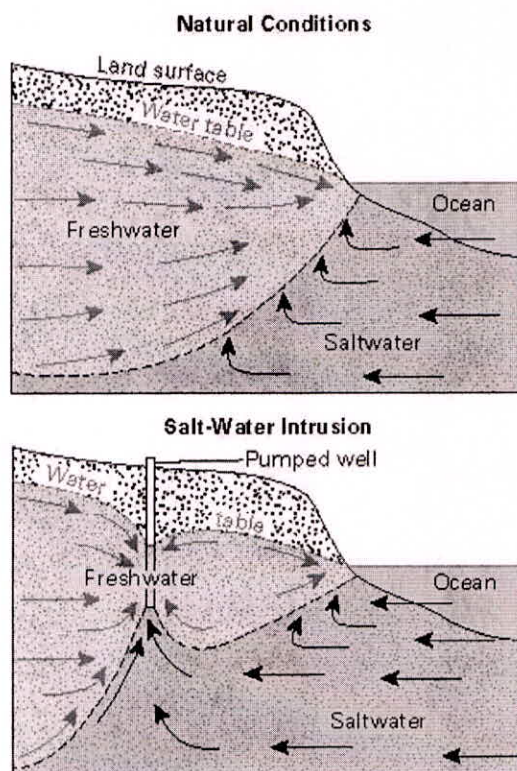


Figure 1.6. The figure shows the difference in natural condition as well as saltwater intrusion condition due to excess groundwater withdrawal (also termed as up-coning).

Source: USGS general internet publication(GW).

1.8.1.2 MECHANISM OF SALINE WATER INTRUSION:

Normally, the denser saline water forms a deep wedge that is separated from the fresh water body by a transition zone of variable density. In some cases, this wedge can extend for many kilometres inland. Providing conditions to remain unperturbed, the saline water body will remain stationary, its position being largely defined by the fresh water potential and hydraulic gradient. However, when the aquifer is disturbed by pumping of the fresh water, sea level change or by changing recharge conditions, the saline water body will gradually move until a new equilibrium condition is achieved. Problems arise when saline water from the deep saline wedge enters pumping wells and affects the water quality. Most commonly, this occurs at individual wells where heavy pumping lowers the fresh water potential in the immediate vicinity of the well and causes saline water to be drawn upwards to the well, a phenomenon known as “up coning”. A similar but potentially more serious problem occurs when a coastal aquifer is overdeveloped on a regional scale. This results in lowering of the fresh water potential throughout the area and progressive and extensive invasion of the aquifer by sea water. In some heavily exploited aquifers, the inflow of sea water may represent a significant component of the aquifer’s flow budget.

Saline water is the most common pollutant in fresh groundwater. Intrusion of saline water occurs where saline water displaces or mixes with fresh water in an aquifer. In a coastal aquifer, there is direct contact between continental fresh water and marine salt water. Besides difference in viscosity between the two fluids, there exist a density change that depends mainly on salinity differences. In a stable system, the fresh water floats on the salt water and a landward sloping interface exists between them. The salt groundwater body adopts the form of wedge resting on the aquifer floor. The fresh water thickness decreases from the wedge toe towards the sea. Since the fresh water flow thickness decreases seaward, the slope of the piezometric head or the water table must increase towards the coast. Thus, the interface is concave upwards.

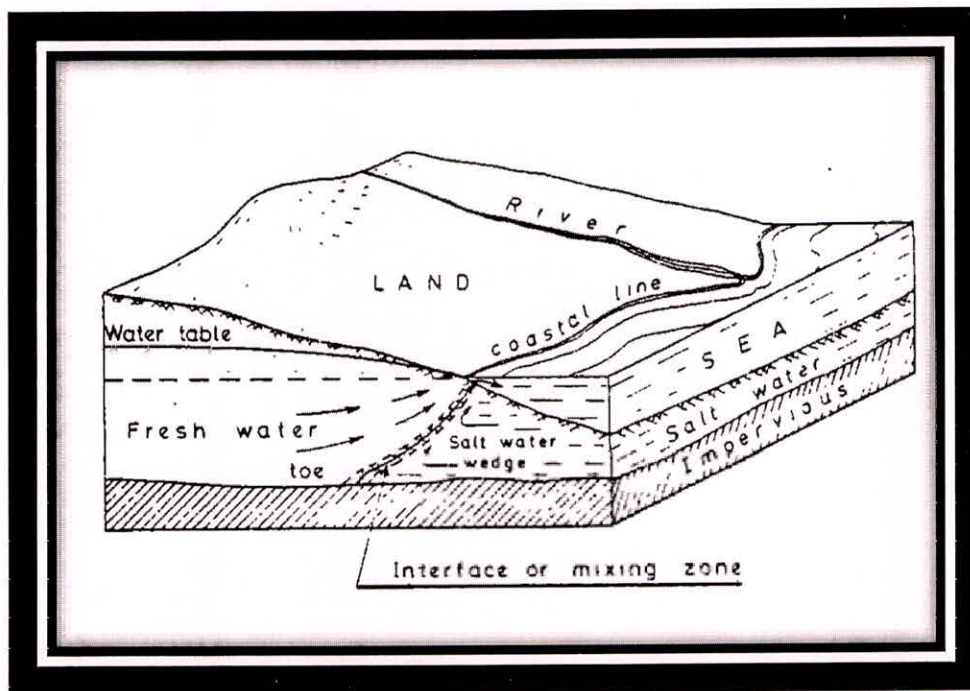


Figure 1.7. The figure is showing the mixing zone mechanism of salt water intrusion.

Source: Todd and Mays (GWH).

Sea water intrusion into fresh groundwater formations generally results from activities of man. In coastal aquifers, sea water intrusion occurs due to invasion of sea water. This situation commonly occurs in coastal aquifers in hydraulic continuity with sea when pumping of wells disturbs the natural hydrodynamic balance. Groundwater abstraction reduces the coastal fresh water discharge and alters the dynamic equilibrium. The final result is a deeper and more penetrating sea water wedge. When abstraction is greater than actual recharge, no final equilibrium position can be attained, but the sea water intrudes very deeply. Fresh water abstractions create local water head drawdowns and when the well is located over the salt water wedge, a salt water up coning develops.

A rapid recharge of fresh water increases the fresh water head. Such situation occurs in water table aquifers where direct recharge by rainfall infiltration is possible and recharge also occurs by irrigation return flows, floods, river channels etc. Both fresh water and salt water flow towards the sea and the mixing zone moves slowly seaward and downwards increasing its slope. The reverse is true in dry period. Sea tides produce the same effect. Many other activities such as urbanization, industrialization, suppression

of irrigated areas, river regulations with upstream dams and deforestation can lead to an increase in the potential for sea water encroachment.

1.8.1.3. MEASURES TO RESTORE GROUNDWATER SYSTEMS IN COASTAL AQUIFERS:

When dealing with the restoration of disturbed groundwater systems in coastal areas, it is necessary to assess:

- The present state, in terms of groundwater tables, piezometric levels and salinity distribution and in terms of exploitation, i.e. location and rates of abstraction.
- The desired state after restoration, in terms of sustainable rates of abstraction and the means and locations thereof, groundwater tables and piezometric levels and the volume of fresh groundwater that should be permanently present in the aquifers as a strategic reserve for emergencies and to cope with fluctuations in the rates of recharge and abstraction.

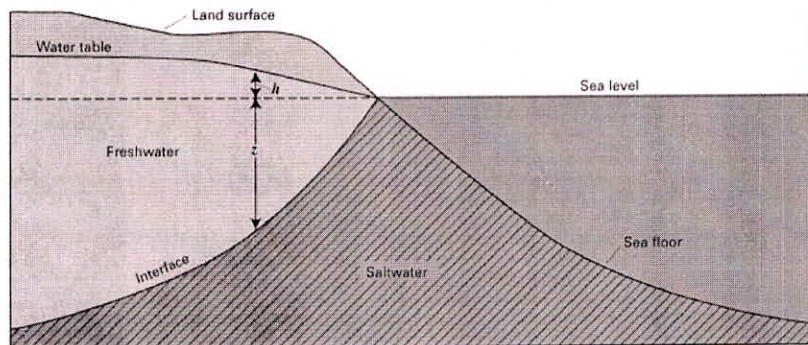
Once the present state is sufficiently known and the desired state has been defined, within the natural, technical and economic limits posed by the aquifer system and its exploitation, the necessary actions can be taken for restoration, where needed. The same actions can and must be taken in those cases which need not to be restored, yet where continuity of a controlled exploitation must be assured. The following measures (van Dam, 1999) can or must be taken to achieve these goals:

- Reduction of the rates of abstraction, in order not to exceed the sustainable yield.
- Relocation of abstraction works – this measure aims at reduction of the losses of fresh groundwater by outflow.
- Increase of natural recharge – this measure is to increase the recharge and therewith the sustainable yield.
- Artificial recharge – this measure is also to increase the recharge and therewith the sustainable yield.
- Abstraction of saline groundwater – this measure aims at increase of the volume of fresh groundwater and at reduction of the losses of fresh groundwater by outflow. The abstracted saline groundwater can under certain conditions be used as a source for desalting.

1.8.1.4 GHYBEN-HERZBERG RELATION:

The first physical formulations of saltwater intrusion were made by W. Badon-Ghijben (1888, 1889) and A. Herzberg (1901), thus called the Ghyben-Herzberg relation. They

derived analytical solutions to approximate the intrusion behavior, which are based on a



number of assumptions that do not hold in all field cases.

Figure 1.8. The figure shows the Ghyben-Herzberg relation.

$$z = \frac{\rho_f}{(\rho_s - \rho_f)} h$$

The thickness of the freshwater zone above sea level is represented as h and that below sea level is represented as z . The two thicknesses h and z are related by the equation $z = 40h$ where ρ_f is the density of

$$z = 40h$$

freshwater and ρ_s is the density of saltwater. Freshwater has a density of about 1.000 grams per cubic centimetre (g/cm^3) at 20 °C, whereas that of seawater is about 1.025 g/cm^3 . The equation can be simplified to,

The Ghyben-Herzberg ratio states, for every foot of fresh water in an unconfined aquifer above sea level, there will be forty feet of fresh water in the aquifer below sea level.

1.8.2. SUBMARINE GROUNDWATER DISCHARGE:

Submarine Groundwater Discharge (SGD) is a hydrological process which commonly occurs in coastal areas. It is described as submarine inflow of fresh-water and brackish groundwater from land into the sea. Submarine Groundwater Discharge is controlled by several forcing

mechanisms, which cause a hydraulic gradient between land and sea. Considering the different regional settings the discharge occurs either as,

- (1) A focused flow along fractures in karst and rocky areas.
- (2) A dispersed flow in soft sediments.
- (3) A recirculation of seawater within marine sediments.

Submarine Groundwater Discharge plays an important role in coastal biogeochemical processes and hydrological cycles such as the formation of offshore plankton blooms, hydrological cycles, and the release of nutrients, trace elements and gases.

LITERATURE REVIEW:

GENERAL:

Groundwater is the reliable source for domestic and other activities and the severity of problem of coastal areas is the seawater intrusion which is the most common form of groundwater contamination around the whole world. Excessive pumping in the coastal zone leads to salinization of the aquifer through encroachment of seawater. Various studies can be found in the literature that deal with the problem of seawater intrusion. These studies can be classified under different categories such as assessment of seawater intrusion; modelling techniques and protection of seawater intrusion. Review of literature relevant to seawater intrusion in the coastal aquifers using isotopic and chemical analysis.

1.9. SEAWATER INTRUSION:

Most of the coastal regions rely on groundwater as their main source of fresh water for domestic, industrial and agricultural purposes. Sea water intrusion is a major concern commonly found in coastal aquifers around the world. Sea water intrusion is the induced flow of seawater into fresh water aquifers primarily caused by groundwater development near the coast. The extent of saline water intrusion is influenced by nature of geological settings, hydraulic gradient and rate of groundwater withdrawal. Many coastal regions in the world experience intensive sea water intrusion in aquifers due to natural and anthropogenic activities. Sea water intrusion is one of the most wide-spread and important processes that degrades the groundwater quality by raising salinity levels exceeding acceptable drinking water standards and endangers future exploitation of coastal aquifers.

Sea water intrusion in fresh water aquifers has also been evaluated from the experimental studies and the same has been carried out by some researchers is presented in the chapter.

M.MohanBabu et al (2013) worked on seawater intrusion in coastal aquifers which has assumed to be of greater importance in recent decades because of the increased demands placed on subsurface water to meet the growing needs of water in large urban areas and agricultural

practices located in the coastal areas in the world. This study aimed at assessing the seawater intrusion along the coastal mandals of Nellore district, Andhra Pradesh. Groundwater were analysed for the following parameters / ions, viz., Hydrogen-ion concentration (pH), EC, TDS, Ca, Mg, K, Na, K, CO_3 , HCO_3 , Cl, I and SO_4 . The general quality of groundwater for drinking purpose was presented. To delineate the seawater intrusion in the study area, Ca/Mg, Cl ($\text{CO}_3 + \text{HCO}_3$), Na/Cl ratios were used. It was observed that Mg was the dominant cation and chloride was the dominant anion in the study area. According to hydrogeochemical ratio the study area seems to be contaminated with salt water intrusion and also this contamination was due to marine source of origin.

H.Harikrishna et al (2012) analysed Kolleru Lake, the largest natural fresh water lake in Andhra Pradesh in India, located between Krishna and Godavari deltas is acting as a natural flood balancing reservoir and is fed directly by water from the seasonal rivers Budameru, Ramileru and Tammileru, and is also connected to the Krishna and Godavari drainage system consists of over 68 inflowing drains and channels. Integrated study using remote sensing, hydrogeology, hydrochemistry and geophysical investigations revealed the extent of salt-water intrusion up to the northern part of the lake which is about 40 km from the coast line. Remote sensing study indicates the various hydrogeomorphic units that contain fresh-water and saline aquifers. Paleo beach ridges are the potable groundwater potential zones in and around the kolleru Lake. Geophysical data were compared qualitatively to delineate the saltwater intrusion zones vertically as well as lateral direction. Chemical analysis of groundwater samples collected from the open wells clearly indicates the level of salinity. Comparison of resistivity and chemical quality is helpful in demarcating the seawater intrusion vertically as well in the lateral direction.

A.Soundarya et al(2012) work aims at assessing the sea water intrusion situation in 9 coastal mandals of Nellore district, Andhra Pradesh. Groundwater levels and groundwater quality for the following parameters/ions, viz., pH, EC, TDS, Ca, Mg, K, CO_3 , HCO_3 , Cl and SO_4 . It is observed that Na was the dominant cation and chloride was the dominant anion in the study area. To delineate the seawater intrusion in the study area, Ca/Mg, Cl/ ($\text{CO}_3 + \text{HCO}_3$), Na /Cl ratios were used. Seawater intrusion was noticed in two mandals in the study area.

Uzoije A.P et al (2014), Saline intrusion has been a major source of groundwater contaminant in coastal regions. The situation has adversely affected groundwater quality. Being an essential source of freshwater for the teeming population over the world and indeed Nigeria and its suitability for various uses is largely dependent on physico-chemical quality, this study therefore selected for its quality assessment, the coastal aquifer of Buguma in rivers state Nigeria. Sodium (Na^{2+}) (288mg/l) chloride (Cl^-) (414.7mg/l) and Nitrate (NO_3^-) (64.45 mg/l) ions dominated the major ions of sample results and also exceeded the Nigerian Standard for Drinking Water Quality NSDWQ 2007 and WHO drinking water standard 2006. Among the trace elements, Fe^{2+} and As^{3+} ions were above the drinking water regulatory limits of NSDWQ and WHO. Classification techniques were employed to provide an assessable information on the chemical composition of the water samples like the major ions in the analysis. The high proportion of Na^{2+} , K^+ and Cl^- as typified by the graphs classified the water as NaK, Cl- type which confirmed saltwater intrusion. The water therefore needs adequate treatment to raise it to portable standards.

Many more literature are given by researchers which shows various aspects of salt water intrusion, their occurrence, and identification method of having salt water intrusion in any particular area.

1.10. GROUNDWATER QUALITY AND WATER QUALITY INDEX:

The groundwater in the coastal aquifer during any project is used to get examined so that the changes that we see after the completion of it should be compared. In every literature review, the evaluation of groundwater is must as the anion and cation concentration is balanced in the area according to the standards. It indicates that water is suitable for drinking purpose or not.

M.MohanBabu et al (2013) who worked on the salt water intrusion of Nellore districts of Andhra Pradesh found that the general quality of groundwater were presented and after the work it was examined that the provided limit and the experimental results were at different platform. The paper observed that Mg is the dominant cation and chloride is the dominant anion in the study area.

H. Harikrishna et al (2012) analysed Kolleru Lake the largest natural fresh water lake in Andhra Pradesh, located between Krishna and Godavari deltas. Chemical analysis of groundwater samples collected from the open wells clearly indicates the level of salinity. This indicates deterioration of quality of groundwater in the area.

A.Soundarya et al (2012) work aims at assessing the sea water intrusion in 9 coastal mandals of Nellore district, Andhra Pradesh. Sea water intrusion was noticed in two mandals in the study area. It is observed that Na is the dominant cation and chloride is the dominant anion in the study area.

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Water quality index:

Water quality is one of the most important factors that must be considered when evaluating the sustainable development of a given zone. Unlike water quantity, which can be expressed in precise terms, water quality is a multi-parameter attribute. The utility of a water quality index relies in the aggregation of information about water-quality parameters at different times and in different places and translating this information into a single score that represents the time period.

Table 1.2. The table provides the basic guide lines for the drinking water.

Sl.no	Constituent	ISI standards desirable	Permissible standards for ISI	Effect if exceeds.
1	pH	(6.5-8.5)	No range	
2	EC ($\mu\text{S}/\text{cm}$)	750	3000	
3	Ca^{+2} (mg/l)	75	200	Encrustation in water supply structure and adverse effects on domestic use.
4	Mg^{+2} (mg/l)	30	100	Encrustation in water supply structure and adverse effects on domestic use.
5	Na^{+} (mg/l)	-	-	
6	K^{+} (mg/l)	-	-	
7	HCO_3 (mg/l)	-	-	
8	Cl^{-} (mg/l)	250	1000	Beyond this limit taste corrosion and palatability are affected.
9	SO_4^{-} (mg/l)	200	400	Beyond this causes gastro intestinal irritation when magnesium or sodium is present.
10	NO_3^{-} (mg/l)	45	100	Beyond this methaemoglobinemia takes place/may be indicative of pollution.
11	F^{+} (mg/l)	01	1.5	Fluoride may be kept as low as possible. High fluoride may cause fluorosis.

{Source: standards provided by ISI (2001)}.

Table 1.3. The table provides the basic guide lines for the drinking water.

Sl. No.	Substance	Requirement (Acceptable Limit)	Permissible limit in the absence of alternate source
1	Magnesium (as Mg^{+2}), mg/l, Max	30	No Relaxation
2	Calcium (as Ca^{+2}), mg/l, Max	75	200
3	Nitrate (as NO_4^-) mg/l, Max	45	No Relaxation
4	Sulphate(as SO_4^-) mg/l, Max	200	400
5	Fluoride (as F^+) mg/l, Max	1.0	1.5
6	Chlorides (as Cl^-) mg/l, Max	250	1000
7	Ammonia (as total ammonia-N), mg/l, Max	0.5	No relaxation

{Source: standards provided by BIS (2003)}.

All the samples are examined and related with the above mentioned limits to know the status of water of the sampling site.

1.11. PREVENTION OF SALT WATER INTRUSION:

Many methods have been utilized to control seawater intrusion. They are, control of pumping patterns, artificial recharge, maintenance of fresh water ridges, installing extraction barriers, combining injection extraction barrier, forming subsurface barriers, installing tide control

gates. The following literature gives an overview of some methods utilised to control seawater intrusion along the coastal zone.

The problem of seawater intrusion into coastal aquifers, their protection and remediation techniques were explained by Lopez- Geta et al (1995). The high level of demand for water in coastal areas often means that those aquifers are exploited intensively, which leads to the seawater intrusion and endangers the sustainable use of the resource. Hydro-geological studies of the aquifers and a thorough assessment of the available resources are very much required to protect the coastal aquifers. Then protection can be based on the appropriate planning of human activities and on suitable, effective management of water resources, permanent control of the water quality and the volume exploited. About remediation, the following standard techniques are applied to resist or even to reverse its advance: reduction and /or redistributing pumping from wells; artificial recharge; coastal collectors; injection barriers; and impermeable barriers. In every case, the aim is to expel salt water from the aquifers and replace it with fresh water.

The corrective measures for seawater intrusion into the groundwater which affects the quality of the groundwater in turn it is unsuitable for the drinking purposes. Elena Abarca et al (2006) implemented two new optimization techniques to overcome this issue in the Llobregat delta region situated in Barcelona of Spain. The first one is linear and consists of maximizing pumping rates while constraining heads to prevent seawater inflow and the second one consists of minimizing the changes from current pumping rates, so as to preserve existing rights, while constraining concentrations, which leads to a nonlinear programming problem. In both cases, corrective measures include a reduction in pumping rates, inland artificial recharge and a coastal hydraulic barrier. The result showed that the Hydraulic efficiency which is greater than 1 proves that it not only increases the resources but also protects the existing ones.

Seawater intrusion is highly dependent on the coastal geology such as deposition channels, presence of fractures etc., as explained by Labregere et al (2006). A good geological characterization must therefore be undertaken to better understand the specific intrusion phenomenon and then select the best approach for remediation. The techniques, such as fresh water injection or salt water extraction, can be used to prevent or retard the salinization process. With either techniques, drilling horizontal wells can bring significant benefits as

compared to vertical wells. They can be drilled with smaller surface footprints, and can allow extracting or injection of significantly larger volumes of water as compared to conventional vertical wells.

Various techniques for control of seawater intrusion in the coastal aquifers are discussed given by researchers. Prevention and control of seawater intrusion into the coastal aquifers is necessary to meet the freshwater demand in the coastal areas.

1.12 OBJECTIVE OF THE STUDY:

The objective of the study is to do assessment of the groundwater quality in the coastal zone of Andhra Pradesh. The specific objectives are as follows:

- Investigating the isotopic and ionic composition of the groundwater, their source of salinity and the principle ionic composition of groundwater contributing to its salinity.
- To check the quality of coastal groundwater (fresh, moderately saline or saline).
- And if salinity exists then in which amount.

CHAPTER -2

2.1 STUDY AREA

GENERAL:

India has a coast line of about 7500 km length, including the main land coast line of about 5400 km. Nearly 25 percent of the total population of India resides in the coastal tracts of the country (CGWB 2014) The eastern coast is characterized by wider coast line when compared to its western counterpart. And in the eastern coast Andhra Pradesh (newly formed Andhra Pradesh in the year 2014) has the longest coast. It lies between north latitudes $12^{\circ} 14'$ and $19^{\circ} 54'$ and, east longitudes $76^{\circ} 50'$ and $86^{\circ} 50'$. According to 2011 census, 1, 63, 900 sq. km. is the total geographical area of Andhra which the fourth largest state of our country.

The coastline significance has been increased after getting separated from Telangana .



Figure2.1. Location of Andhra Pradesh in India.

2.2. PHYSIOGRAPHY, DRAINAGE, CLIMATE RAINFALL AND SOIL:

Physiographically, Andhra Pradesh is divided into three distinct zones, viz., Coastal Plains, Eastern Ghats and Western Pedepains. The landforms, altitude and drainage pattern are different in each zone. The first two units stretch from Northeast to Southwest in a narrow strip while the western pedepains occupy rest of the area.

2.2.1. COASTAL PLAINS-

The coastal plains stretch from Kalingapatnam (Srikakulam district) in the north to Pulicot (Nellore district) in the south along a narrow strip, which broadens in the middle along Godavari - Krishna deltas (80 sq.km). The altitude of coastal plain ranges from sea level at the coast to 150 - 200 mamsl on the west.

2.2.2. EASTERN GHATS -

The Eastern Ghats follow the Coastal Plains stretching closely from one end to the other except in area between the Godavari and Krishna rivers. The hill ranges trend in NE - SW direction in the north and in N-S direction in the south and attain elevation of 600 to 1200 mamsl. The Nallamala, Erramala, Seshachalam, Velikonda and Palakonda hills falling in Rayalaseema region, cover southern section of Ghats.

2.2.3. WESTERN PEDEPLAINS -

The physiographic unit western pedeplain occur in parts of Rayalaseema region (Kurnool and Anantapur districts) exhibits rolling topography with flat to undulating tracts. The elevation varies from 150 to 600 m amsl except at places where it is overlain by basaltic lava flows (600 to 900 mamsl).

2.2.4. DRAINAGE -

The State is drained by 40 major and minor rivers. The important rivers are Godavari, Krishna, Pennar, Palar, Vamsadhara, and Nagavalli. Godavari and Krishna rivers and their tributaries drain the northern and central part and Pennar River drains the southern part of the state before confluence Bay of Bengal. There are 3 major basins and 11 medium river basins in the state. The major river basins are Godavari, Krishna and Pennar and medium basins are Vamsadhara, Nagavalli, Sarada, Yeleru, Gundlakamma, Palleru, Kurieru, Swarnamukhi and inter stream areas between Krishna and Godavari basins. The drainage pattern is generally dendritic with wide valleys in western peneplain. The drainage in eastern ghat is coarse and dendritic with steep and narrow valleys. Youthful streams and valleys mark the eastern coastal tract intersected by innumerable feeder and distributory canal system. The mature

river courses of Godavari, Krishna and Pennar meanders through the vast areas covered by deltas as well as coastal plains. Most of the smaller streams feed innumerable tanks.

The Tungabhadra, Vedavati, Hindri, and Paleru rivers drain the northern part of the state. River Penna flows across southern part of the state with its tributaries Chitravati, Papaghni and Cheyyeru and drains major part of Rayalaseema region and Nellore district of coastal region. The drainage basins are characterised by undulating topography comprising a series of ridges and valleys interspersed by hill ranges. The deltas of rivers are very extensive and characterized by considerable thickness of alluvial material. Vamsadhara and Nagavalli rivers with their distributaries drain the northeastern part of the state in Srikakulam district. Visakhapatnam district is mostly drained by local rivulets like Sarada. River Eleru drains east Godavari district while Yerrakalave, Tammileru drain West Godavari district. Nellore district is drained by Pennar, Swarnamukhi and Arani rivers.

2.2.5. SOIL –

There are wide variety of soil occur in the State; Red soil, Lateritic soil, Black cotton soil, Deltaic alluvium soil, Coastal soil and Saline soil. Red clayey soil occur predominantly in Srikakulam, Visakhapatnam, East Godavari and West Godavari districts in coastal region. Black cotton soil commonly occur in Krishna and Guntur districts. Red earths with loamy soil and red sandy loamy soil and lateritic soil occur in Prakasam and Nellore districts.

2.2.6. CLIMATE-

The climate is tropical in nature and is influenced by topographical variations and maritime influence. The Eastern Ghats in Vishakhapatnam and its neighbourhood play a significant role, which acts as a barrier to easterly winds in association with depression from Bay of Bengal during the south-western monsoon.

2.2.7. RAINFALL-

The annual normal rainfall of A.P is 952mm. The average rainfall from the month of January to October is 149mm. July to November are the rainiest months of the year. The water levels are deep in the month of May and shallow during November. Water level rises takes place

during August, November and January depending on the monsoon rainfall and level of groundwater development. Approximately all coastal districts have the rainfall of {1000-1200}. This is the information of 2014-2015 CGWB report.

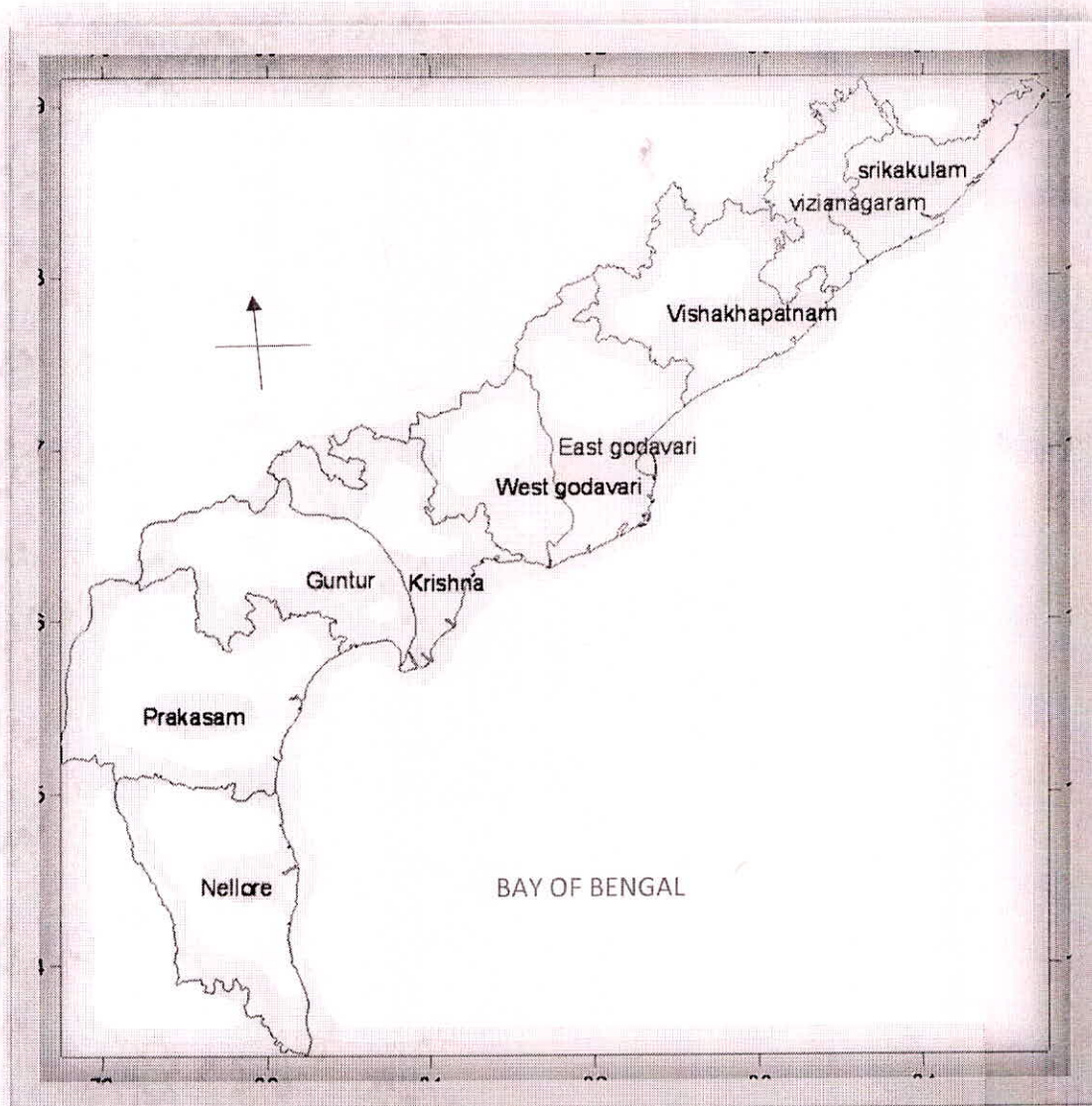


Figure 2.2. The coastal districts of Andhra Pradesh created on SURFER ®.

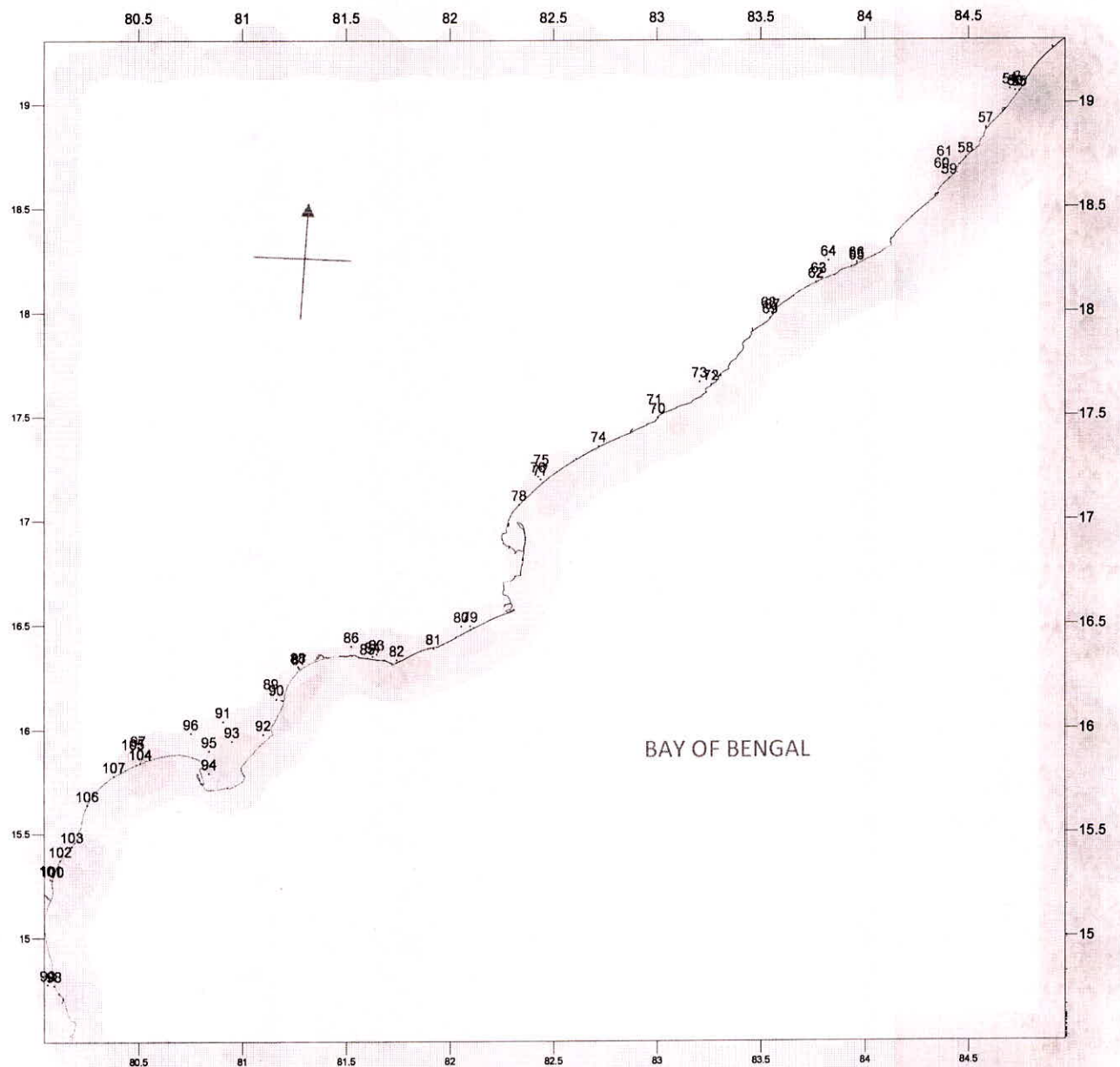


Figure 2.3. The coastline of Andhra Pradesh which is created on SURFER®.

Table2.1. -Coastal mandalam and the population of Andhra Pradesh.

COASTAL DISTRICTS	COASTAL BLOCKS/MANDALAM	DISTRICT POPULATION (2011)
Srikakulam	Tekkali Sub Division: Ichchapuram , Kaviti, Sompeta, Mandasa, Vajrapukotturu, Santhabommali Srikakulam Sub-Division: Polaki, Gara, Srikakulam, Etcherla, Laveru, Ranastalam	26,99,471
Vizianagaram	Bhogapuram and Pusapatirega	23,44,474
Visakhapatnam	Bheemunipatnam, Visakhapatnam (Rural & Urban), Pedagantyada, Paravada, Achutapuram, Rambilli, S. Rayavaram, Nakkapalle, Payakaraopeta	42,88,113
East Godavari	Thondangi, Kothapalle, Kakinada (Rural & Urban), Thallarevu, Katrenikona, Uppalaguptam, Allavaram, Mamidikuduru, Malikipuram, Sakshinetipalle	51,51,549
West Godavari	Narasapuram and Mogalthur	39,36,966
Krishna	Kruthivennu, Machilipatnam, Koduru, Nagayalanka	45,29,009
Guntur	Repalle, Nizampatnam, Karlapalem, Bapatla	48,89,230
Prakasam	Chirala, Vetapalem, Chinaganjam, Naguluppalapadu, Ongole, Kothapatnam, Tangutur, Singarayakonda, Ulavapadu,	33,97,448

	Gudluru	
Nellore	Kavali, Bogole, Allur, Vidavalur, Indukurpeta, Thotapalligudur, Muthukur, Chillakur, Kota, Vakadu, Sullurupeta	29,66,082
Total Population of coastal District		3,42,02,342

2.3. DESCRIPTION OF THE TABLE:

2.3.1 SRIKAKULAM-

Srikakulam is located in the extreme north eastern direction of the state. It is situated within the geographic co-ordinates of 18°20' and 19°10' N and 83°50' and 84°50' E. Srikakulam district occupies an area of 5,837 square kilometres (2,254 sq mi). According to the 2011 census, it has population of 2,699,471.

It has 38 mandals under the three revenue divisions, and mainly the coastal mandals of the districts are under two sub division [Tekkali Sub Division: Ichchapuram, Kaviti, Sompeta, Mandasa, Vajrapukotturu, Santhabommali and Srikakulam Sub-Division: Polaki, Gara, Srikakulam, Etcherla, Laveru, Ranastalam].

2.3.2 VIZIANAGARAM-

Vizianagaram district is a northern coastal district of Andhra Pradesh. The district is bounded on the east by the district of Srikakulam, southwest by the district of Visakhapatnam, southeast by the Bay of Bengal, and northwest by the state of Odisha. It is situated within the geographical co-ordinates of 17° 15' and 19° 15' of the northern latitudes and 83° 00' and 83°45' of the eastern longitudes. And population of about 23, 44,474.

It has 34 mandals out of which two lies in the coastal mandals [Bhogapuram and Pusapatirega].

2.3.3 VISHAKHAPATNAM-

Visakhapatnam district is one of the north coastal districts of Andhra Pradesh. The district is sandwiched between the Eastern Ghats and Bay of Bengal. The district lies between north latitude 17° 15' and 18° 30' and east longitude 78°30' and 83°30' covering an area of 11,342.84 sq.km. Population of 42, 88,113 in the districts.

It has four division of mandalam and that of total 43 mandals. The four divisions are - Anakapalle Division, Narsipatnam Division, Paderu Division, Visakhapatnam Division. Out of which these are coastal mandals [Bheemunipatnam, Visakhapatnam (Rural & Urban), Pedagantyada, Paravada, Achutapuram, Rambilli, S. Rayavaram, Nakkapalle, Payakaraopeta].

2.3.4 EAST GODAVARI-

The East Godavari district is one of the nine coastal districts of Andhra Pradesh and is known for its historical importance. The district enjoys a unique place and is known as “rice bowl” of Andhra Pradesh. The district forms part of the Godavari delta region and is endowed by a vast potential of surface water resources. It has emerged as the most populous district of the state with a population of 5,151,549. The district lies between north latitude 16°30' and 18°00' and east longitude 81°30' and 82°30' spreading over an area of 10,807Sq.km.

It has total 64 mandals under seven revenue division which are, Amalapuram Division, Etapaka Division, Kakinada division, Rajahmundry division, Ramachandrapuram, Rampachodavaram. Out of there are coastal mandals [Thondangi, Kothapalle, Kakinada (Rural & Urban), Thallarevu, Katrenikona, Uppalaguptam, Allavaram, Mamidikuduru].

2.3.5 WEST GODAVARI-

West Godavari district is one of the 13 districts in the Indian state of Andhra Pradesh. The district is situated in Coastal Andhra region of the state. As of 2011 census of India, it has an

area of 7,742 km² (2,989 sq mi) and a population of 3,936,966. It is located between North Latitudes 16 °51' and 17° 30' and East Longitudes 80 °50' and 81° 55'.

The districts has 46 mandals under 4 revenue divisions - Eluru division, Jangareddygudem division, Kovvur division, Narasapuram division. From the above mentioned mandalam only two carried out by coastal area as Narasapuram and Mogalthur.

2.3.6 KRISHNA-

Krishna district is one of the 9 coastal districts of Andhra Pradesh and agriculturally it is an important district. The district has a coastline of 88 km. Krishna district is an administrative district in the Coastal Andhra region of the Indian state of Andhra Pradesh. It has an area of 8,727 km² and had a population of 45,29,009 as per 2011 census of India. The district lies between North latitude of 15° 43' and 17° 10' and East longitudes of 80° 00' and 81° 33' with an aerial extent of 8797 km².

The revenue divisions are divided into 50 mandals in the district and the four revenue divisions, namely Vijayawada, Nuzvid, Machilipatnam and Gudivada, out of which these are Kruthivenu, Machilipatnam, Koduru, Nagayalanka coastal mandals.

2.3.7 GUNTUR-

Guntur district is one of the Central coastal districts of Andhra Pradesh. It has a geographical area of 11,328 sq. kms. It lies between North latitudes 15°18' & 16°50' and East longitudes 79°10' & 80°55'. It has a coastline of approximately 100 km and is situated on the right bank of Krishna River, that separates it from Krishna district and extends till it empties into the Bay of Bengal.

It comprises 57 mandals under administrative control of 3 divisions namely Narasaraopet, Guntur and Tenali, and that of these lies in the coastal areas - Repalle, Nizampatnam, Karlapalem, Bapatla.

2.3.7. PRAKASAM-

The Prakasam district is bounded in the North by Guntur district, in the south by Nellore and in the East by Bay of Bengal and lying between north latitudes 14°57' and 16°17' and Eastlongitudes 78°43' and 80°25'. It is the 3rd largest district in the state with an area of 17,626 km² and has a population of 3,392,764 as per 2011 census of India.

The prakasam district has 56 mandals under 3 revenue divisions and the divisions are kandukur division, markapur division, ongole division. And the Chirala, Vetapalem, Chinaganjam, Naguluppalapadu, Ongole, Kothapatnam, Tangutur, Singarayakonda, Ulavapadu, Gudluru are the coastal mandals.

2.3.8. NELLORE-

Nellore district (officially: Sri PottiSriramulu Nellore district), located in Coastal Andhra region, is one of the 13 districts of Andhra Pradesh. The population of the district according to the Census 2011 was 2,966,082 of which 29.07% were urban. The district is bordered by the Bay of Bengal to the east, Kadapa district to the west and Prakasam District to the north. The district has a coastline of 169 km. It is endowed by good rainfall and surface water.

It has 46 mandals under 5 revenue divisions which are Atmakur division, Naidupeta division, Nellore division, Gudur division, Kavali divisions out of which Kavali, Bogole, Allur, Vidavalur, Indukurpeta, Thotapalligudur, Muthukur, Chillakur, Kota, Vakadu, Sullurupeta are coastal mandals.

Table2.2. - Coastal districts and the hydrogeology of coastal AP.

COASTAL DISTRICTS	COASTAL HYDROGEOLOGY
Srikakulam	Alluvium, Khondalite and charnokite Rivers: Vamsadhara and Nagavali
Vizianagaram	Alluvium, Khondalite, granitic gneiss
Visakhapatnam	Granitic gneiss, Charnokites, Khondalite, sandstone & alluvium Rivers: Tandava, Varaha, Sarada and Gosthani
East Godavari	Laterite, alluvium, basalt, Rajamundri&Tirupati SST, Granitic gneiss, Khondalite Rivers: Godavari, Pampa, Thandava and Yeleru
West Godavari	Alluvium, Dekkan Traps, Rajamundri&Tirupati SST, Golappali formation Rivers: Godavari, Yerrakaluva, Tammileru, Ramileru and Kolleru
Krishna	Gneiss, Charnokite, Khondalite, meta-sediments, sandstone, alluvium Rivers: Krishna, Muniyeru, Tammileru, Budameru
Guntur	Alluvium, Shale, sandstone, limestone with shale, quartzite with conglomerate, quartzite with shale, dolomite, shale with phyllite, khondalite, granite Rivers: Krishna, Gunlakamma, Gundlavagu, DindiVagu, Naguleru, Gadidelavagu, Edduvagu
Prakasam	Alluvium, Laterites, sandstone, metamorphic Rivers: Krishna, Pennar, Musi, Manneru, Paleru, Gundalakamma

Nellore	Alluvium, laterites, sandstone, quartzite & shale, amphibolites and polytic schists Rivers: Pennar, swarnamukhi, Manneru, Upputeru Lake: Pulicat
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2.4. DESCRIPTION OF TABLE:

2.4.1. SRIKAKULAM-

The district is underlain by variety of geological formations from the oldest Archaeans to Recent Alluvium. The Archaean Group of rocks includes Khondalites and Charnockites of Eastern Ghat Super Group and Granitic gneisses of Migmatite Group. The Gondwana rocks which are represented by sandstones are of very limited aerial extent. These sandstones occur as outlier in Ranastalammandal on western part of the district. The thickness of this formation is more than 220 m. The recent sediments constitute coarse to fine sands, gravels, silts and clays.

Structurally the area is highly disturbed as evidenced by the structurally controlled rivers viz: Vamsadhara and Nagavali which are observed to flow in the faulted zone trending NW-SE direction. The main rivers drain the district are Vamsadhara and Nagavali. The other important rivers flowing in the district are Suvarnamukhi, Vegavati, Mahendra Tanya and Bahuda. Among the rivers Vamsadhara, Nagavali and Suvarnamukhi are perennial.

2.4.2. VIZIANAGARAM-

The hydrogeological conditions prevailing in the district generally depends on various factors like climate, rainfall, topography, geological setting and structure. In turn the occurrence and movement of groundwater also depend on these factors. The rocks occurring in the district can be broadly classified as two types viz; hard and soft rocks. Crystalline formations like khondolites, charnockites, migmatites and gneisses etc. can be grouped as hard rocks, while the unconsolidated formations like the alluvial sediments can be classified

as soft rocks. The semi consolidated formations like sandstones are grouped under soft rocks, though limited in occurrence.

2.4.3. VISHAKHAPATNAM-

The district is underlain by variety of geological formations from the oldest Archaeans to Recent Alluvium. The Archaean group of rocks includes Khondalites and Charnockites of Eastern Ghat super group and Granitic gneisses of Migmatite group. The Gondwana rocks which are represented by sandstones are in very limited aerial extent. The recent alluvium is prevalent along the rivers. Ground water occurs in almost all geological formations. From the ground water point of view, the aquifers in the district can be broadly classified into hard formations (khondalites, charnockites, granitic gneisses etc.) and soft formations (sand stones and alluvium). Ground water occurs under unconfined to semi-confined conditions in the hard formations, while it occurs under unconfined to confined conditions in soft formations.

The most important rivers drained in the district are Machikund, Tandava, Varaha, Sarada and Gostani. Most of the rivers are ephemeral in nature. However, some of the tributaries of Machikund are perennial with indications of substantial ground water discharge. Almost all the rivers and streams experience flash floods during rainy season. A good number of springs exist in Paderu and Araku areas. The district is characterized by sub-dendritic to dendritic nature of drainage pattern and is of coarse texture. In general the density is in the range of 0.6 to 1/Km². Many of the hill streams in Paderu valley disappear on entering the plains due to high permeability of the pediment gravels. The disappearance of streams in and along the hill slopes is contributing to the ground water, which is again discharged through the silty soils at lower elevations.

2.4.4. EAST GODAVARI-

The Godavari River is the major river drain the district, which is perennial and flows along the western boundary of the district. South of Rajahmundry the river bifurcates into two viz., Gautami Godavari in the East and Vasista Godavari in the West. The Godavari River further splits into smaller arms before it debouches into the Bay of Bengal. The other important rivers and tributaries of Godavari flowing in the district are Gondiyeru, Pamuleru, Polavaramvagu, Sileru River, Suddagedda, Yeleru, Madeyeru and Tandava. The general drainage pattern is dendritic to sub-dendritic. The drainage density varies from less than 0.4

km/sq.km in poorly drained alluvial areas which covers the entire southern parts of the district to 0.6 km/sq.km in the Northern parts occupied by crystalline rocks.

The district is underlain by different geological formations comprising oldest Archaeans to Recent Alluvium. The rock types are classified as consolidated, semi-consolidated and unconsolidated formations. The consolidated formations include khondalites, charnockites & granitic gneisses of Archaean group, deccan traps of Tertiary period. The semi consolidated formations are represented by tertiary and upper gondwana formations like Rajahmundry & Tirupati sandstones and unconsolidated formations comprise deltaic and river alluvial deposits of Quaternary period.

2.4.5. WEST GODAVARI-

The district is underlain by Archaean crystalline, Gondwanas, Deccan Traps, Tertiaries and alluvial sediments. About 45% of the district is underlain by Gondwana formations, 40% is underlain by Alluvium and the rest is by Archaean crystalline rocks.

The district is mainly drained by Godavari, Yerrakalava, Tammileru and Ramileru rivers. The river Godavari enters the district near the northeastern corner and after flowing a distance of 72 km, the river bifurcates into Gautami and Vasishta rivers at Vijeshwaram. The Gautami River which marks the district boundary, debouches into Bay of Bengal at Antervedi, draining about 20% of the district area. The other prominent rivers/streams in the district are Yerrakalava, Tammileru, Ramileru, and Guvvaleru. Yerrakalava joins Godavari River while Tammileru and Guvaleru join Kolleru Lake. The Kolleru Lake, the biggest fresh water lake in the country, is situated in the southwestern part of the district. The drainage is mainly dendritic in the northern part of the district and appears to be controlled by structure. Drainage density is more in the northern part and is sparse in southern part. The delta area is served by Godavari canal system and numerous other drains.

2.4.6. KRISHNA-

The district is underlain by variety of geological formations comprising from the oldest Archaeans to Recent Alluvium. Hydrogeologically these formations are classified as consolidated (Hard), semi-consolidated (Soft) and unconsolidated (Soft) formations. The

consolidated formations include crystallines (khondalites, charnockites and granitic gneisses) and metasediments (Limestones, shales, phyllites and quartzites) of Archaean and Precambrian periods respectively. The semi consolidated formations are represented by Tertiary formations (Rajahmundry & Gollapalli sandstones) and unconsolidated formations comprise deltaic alluvial deposits of Quaternary period. Consolidated formations occur in the northern part of the district. Among consolidated formations occurrence of metasediments is restricted to NW part of the district. Semiconsolidated formations occur in the northeastern part of the district and its extension is limited to small area. Unconsolidated formations occur in the southern part of the district i.e., in the delta area. Ground water occurs in all most all geological formations and its potential depends upon the nature of geological formations, geographical setup, and incidence of rainfall, recharge and other hydrogeological characters of the aquifer.

The Krishna is the major river which drains the district, it is perennial in nature and flows along the western boundary of the district. South of Avanigadda the river bifurcates into four branches before it debouches into the Bay of Bengal. The other important rivers flowing in the district are Muniyeru, Tammileru and Budameru. The general drainage pattern is dendritic to sub-dendritic. The drainage density is high in consolidated formations, low in semi-consolidated formations, whereas in alluvial areas the density is meager. Kolleru Lake is located between Krishna and Godavari delta and spans into two districts - Krishna and West Godavari. It is the largest freshwater lake in Asia. The lake serves as a natural flood-balancing reservoir for these two rivers. The lake is fed directly by water from the seasonal Budameru and Tammileru rivers, and is connected to the Krishna and Godavari systems by over 68 inflowing drains and channels. The lake is an important habitat for an estimated 20 million resident and migratory birds. It is known the world over for the famous Kolleru Bird Sanctuary.

2.4.7. GUNTUR-

The important rivers that drain through the district are the Krishna and Gunglakamma. The river Krishna is the major river. Important tributaries include Gundlavagu, Dindivagu, Naguleru, Gadidelavagu, Edduvagu. The drainage pattern, in general, is straight, parallel to sub-parallel and dendritic. All the streams are ephemeral in nature. The Krishna River is perennial, whereas most of the other streams are intermittent to ephemeral in nature.

Table 2.3.-These are the sampling location and number of samples that has been collected from the 9 coastal districts of the Andhra Pradesh (study area) and the date on which samples were collected.

SITE ID	LOCATION	DATE
SGD 54	EDUPURAM	31-05-2016
SGD 55	DONKURU BEACH	31-05-2016
SGD 56	BURJA PADU	31-05-2016
SGD 57	BARUVA ,M.P. SCHOOL	31-05-2016
SGD 58	SIVASAGAR BEACH,AKKUPALLI	01-06-2016
SGD 59	KR PETA BEACH	01-06-2016
SGD 60	PUNDI, T JUNCTION, NAUPADA-PALASA ROAD	01-06-2016
SGD 61	BENDI GATE	01-06-2016
SGD 62	JURUPALEM BEACH	02-06-2016
SGD 63	KOTCHERLA	02-06-2016
SGD 64	SANTHASEETHARAMPURAM NEAR KUPPILI(DEPTH>200FT)	02-06-2016
SGD 65	KUNDUVANIPETA (BEACH)	02-06-2016
SGD 66	KUNDUVANIPETA (VILLAGE)	02-06-2016
SGD 67	MOKKAM BEACH (NEAR POLLAMA MANDIR) depth>300ft	03-06-2016
SGD 68	KONGAVANIPALEM	03-06-2016
SGD 69	CHAPALLA-KANCHERU(depth=80-100ft	03-06-2016
SGD 70	PUDIMADAKA, NEAR ACHUTAPURAM	04-06-2016
SGD 71	NEAR SBH, DUPPITURU BEACH,BHOGAPURAM	04-06-2016
SGD 72	AGRIGOLD RESORT, NEAR WEREDA BEACH(depth=30ft)	04-06-2016
SGD 73	PEDAGANTYADA, B.C. ROAD (DEPTH=200FT)	04-06-2016
SGD 74	RAJAYYAPETA BEACH	05-06-2016
SGD 75	SUNGA VRUKSHAM VILLAGE NEAR THONDANGI ROAD	05-06-2016
SGD 76	PATALKODADAA VILLAGE,A.KOTHAPALLE	05-06-2016
SGD 77	GORSPALEM VILLAGE,PERUMALLAPURAM	05-06-2016
SGD 78	UPPADA BEACH	05-06-2016

SGD 79	S.YANAM(VILLAGE)((depth=10ft)	06-06-2016
SGD 80	CHALLAPALLI	06-06-2016
SGD 81	KARAVAKA(depth=15ft)	06-06-2016
SGD 82	ADARSHNAGR,ANTARAVEDI	06-06-2016
SGD 83	LAKSHYAVARAM MARKET, ON PEDAMANIVANI LANKA(depth=12ft) ,NEAR THURPUTALLU ROAD	07-06-2016
SGD 84	CHINNAMAINVVANNI LANKA,KUMMARAPURUGUPALEM	07-06-2016
SGD 85	CHURCH, PUBLIC BATH, NEAR PERUPALEM BEACH	07-06-2016
SGD 86	MUTYALAPALLI MODI,KALIPATNAM NEAR PALAKOL-NARSAPUR ROAD	07-06-2016
SGD 87	G.PEDDA PATNAM BEACH(DEPTH 300FT)	07-06-2016
SGD 88	PEDA PATNAM	07-06-2016
SGD 89	MACHILIPATNNAM(DEPTH 20FT),BUTTAIPETA NEAR STATION ROAD	08-06-2016
SGD 90	GILAKALADINDI	08-06-2016
SGD 91	PULLIGADA, NEAR HEBRON PRAYER HOUSE(depth=40ft)	08-06-2016
SGD 92	PALAKAYATIPPA(depth 11ft)	08-06-2016
SGD 93	CHODAVARAM(Depth 15ft)	08-06-2016
SGD 94	LANKEVANIDIBBA CYCLONE CENTRE(Depth 480ft)	09-06-2016
SGD 95	OUTSKIRTS OF THUMMALA	09-06-2016
SGD 96	PALLAPATLA(20ft)	09-06-2016
SGD 97	NIZAMPATNAM, NEAR PRTROL PUMP, (depth 12ft),BAPATLA EAST RURAL	09-06-2016
SGD 98	THATICHETLA PALEM(NEW BEACH ROAD)	10-06-2016
SGD 99	IN BETWEEN JUVVALADINNE AND SIDDAVARAPU VENKATESUPALEM	10-06-2016
SGD 100	PAKALA BEACH(5ft)	10-06-2016
SGD 101	PAKALA	10-06-2016
SGD 102	ETHAMUKKALA BEACH	10-06-2016
SGD 103	KOTHAPATNAM BEACH(depth 25 to 30 ft	10-06-2016
SGD 104	BAPATLA,SURYA- LANKA BEACH ROAD	11-06-2016
SGD 105	AMAR CHETTI WARI PALEM,MADDIBOINAVARIPALEA	11-06-2016
SGD 106	PEDDA GANJAM	11-06-2016

2.5. SUMMARY:

This full chapter explains about the study area on which this report is based on. The chapter explains the coastal mandals of the coastal zone and the number of people residing in the place because all these can be a factor of depletion. And also the hydrogeological condition of the area and the drainage which helps to understand the background of the area. And all the sampling locations are given along with the date it was collected.

CHAPTER -3

3.1. GENERAL:

This chapter is focussed about the methodologies that have been used in the following report. Groundwater is one of the earth's most precious water resources. Its quantitative and qualitative studies are very important for the water resources protection and planning. The high level of demand for fresh water in coastal areas often means that such aquifers are exploited intensively, (extraction per unit area)- wherever the freshwater is available and extensively (area per unit aea), which leads to the encroachment of seawater intrusion and endangers the sustainable use of the resource. Aquifer over-exploitation has resulted in seawater intrusion on many occasions during the past and also the population and economic growth, tends to increase the pressure on available reserves.

One of the most common method for assessing seawater intrusion through an aquifer in coastal belt is a periodic analysis of groundwater chemistry. This study aims to understand the occurrence of seawater intrusion from the hydro geochemical studies and the source from which it is occurring. To achieve the objectives of the study has been carried out by following techniques i. Firstly, through the study of isotopes. ii. By hydro geochemical studies.

3.2. ISOTOPIC ANALYSIS:

BASICS:

Thousands and lakhs of physical and chemical combinations (mixtures and compounds) elements have been discovered with amazing properties. Depending upon the specific properties of various atoms and molecules, a number of applications have been discovered in

a variety of fields. Isotope Hydrology is comparatively a new field of research and deals with the use of different atoms of elements and molecules of compounds for various hydrological investigations.

Proton - positively charged; mass - 1.672648×10^{-27} Kg ; **Electron** - negatively charged; mass - 9.10986×10^{-31} Kg or 1/1836 times of mass of proton; **Neutron** - neutral (no charge); mass - $1.6749543 \times 10^{-27}$ Kg.

The number of proton and number of electron are always same in a stable atom. This number is called the atomic number of an atom and is denoted by a symbol (Z). The number of neutron (N) plus either the number of protons or electrons (normally number of neutrons and number of protons) is called the atomic mass or weight of an atom and its denoted by a symbol (A), i.e. $A = Z + N$.

The term isotope is used to differentiate and distinguish the atoms of a same element and atoms of different elements showing similarities in physical and chemical properties. Isotopes are the atoms of an element having same atomic number (Z) but different atomic weight (A). In other words, the atoms of an element having different number of neutrons (N) but same number of protons or electrons are called isotopes. For example, hydrogen has three isotopes having the same atomic number of 1 but different atomic masses or weights of 1, 2 and 3 respectively i.e.,

1_1H_0 - Only one proton in nucleus and one electron revolving around the nucleus in an orbit.

2_1H_1 - One neutron added to the nucleus of 1_1H_0 atom.

3_2H_2 - One more neutron added to the nucleus of 2_1H_1 .

Similarly oxygen has eleven isotopes, ${}^{12}O$, ${}^{13}O$, ${}^{14}O$, ${}^{15}O$, ${}^{16}O$, ${}^{17}O$, ${}^{18}O$, ${}^{19}O$, ${}^{20}O$, ${}^{21}O$ and ${}^{22}O$, but except ${}^{16}O$, ${}^{17}O$, and ${}^{18}O$, all other isotopes are radioactive and their existence in nature is very small (half-life vary from 150 seconds to few femo seconds - of the order 10^{-15} seconds) therefore, the normal talk is only about three isotopes of oxygen i.e., ${}^{16}O$, ${}^{17}O$, and ${}^{18}O$.

3.3. CLASSIFICATION OF ISOTOPES:

Isotopes can be classified in two important categories (i) stable isotopes and (ii) unstable isotopes.

3.3.1. STABLE –

Stable isotopes are the atoms of an element, which are satisfied with the present arrangement of proton, neutron and electron. The atoms of an element which do not decay with time or take infinite time to decay are called stable isotopes of that element. Over 2000 isotopes of 92 naturally occurring elements have been identified out of which several hundred are stable isotopes. But for hydrological investigations, more importance is given to the hydrogen and oxygen stable isotopes. As both provides the good idea of water condition and the source through which it gets changed. For example, ^1H and ^2H are stable isotopes of hydrogen and (^{16}O , ^{17}O and ^{18}O) are of oxygen which are stable except the ^3H which is unstable.

As it is known, water molecule is made up of two hydrogen atoms and one oxygen atom therefore, many combinations are possible in the series(18) out of which $^1\text{H}^1\text{H}^{16}\text{O}$, $^1\text{H}^1\text{H}^{16}\text{O}$, $^1\text{H}^2\text{H}^{16}\text{O}$, $^1\text{H}^2\text{H}^{18}\text{O}$, $^1\text{H}^1\text{H}^{17}\text{O}$ and $^1\text{H}^2\text{H}^{17}\text{O}$ are important.

Measurements of stable isotopes are done in terms of abundance ratios i.e. atomic mass of heavy atom to the atomic mass of light atom. For example heavy water $^2\text{H}_2^{16}\text{O}(\text{D}_2^{16}\text{O})$ has a mass of 20 compared to normal water $^1\text{H}_2^{16}\text{O}$ which has a mass of 18. Similarly, heavier stable molecule of water D_2^{18}O has a mass 22. This is because of the variation in the number of neutrons. However, the absolute abundance ratio of isotopes is not usually measured in natural waters and in other components.

3.3.2. UNSTABLE-

Unstable isotopes are the atoms of an element which do not satisfy with the present arrangement of atomic particles and disintegrate by giving out alpha (α), beta (β) particles and/or gamma (γ) radiation etc. and transform into another type of atom. This process continued till the stable nuclide (element) is formed. Because of disintegration or the property of giving out radiation, the unstable isotopes are also called radioactive isotopes.

The earth is called as a water planet because water is abundant in all phases on it. Water is distributed in reservoirs; oceans, ice caps, groundwater, lakes, inland seas, atmosphere and rivers. The composition of hydrogen and oxygen isotopes in water bodies vary in time and space due to various hydrological processes. Hence, the origin and the circulation of water can be traced by the hydrogen and oxygen isotope abundance. Stable isotopes of hydrogen and oxygen have been used to trace water circulation in various scales in time and space. They have been found to be good tracers to understand the hydrological system. Isotope hydrology is the fingerprints of water and has an application of tracing the groundwater pollution source, sources of salinity and the salt water intrusion.

3.4. SAMPLING OF GROUNDWATER:

Sampling groundwater for deuterium and oxygen-18 analyses is very simple. Only one 10 ml sample is required for D and ^{18}O , but to be on safer side and for repeated measurements, minimum 60 ml sample should be collected in a high-density polyethylene bottles. Depth-wise or depth water samplers can be collected from specially developed piezometers or domestic wells (shallow intermediate depth hand-pumps and deep tube wells) respectively. Sampling should be followed after withdrawal of water equal to or more than the existing volumes of bore hole water so that the sampled water is not contaminated from any pre-existing water but, is representative of the dynamic aquifer water. Springs and artesian wells may be considered good source of groundwater sampling as aquifer water is continuously flowing out from the ground surface. Open-wells should be avoided (as it is difficult to employ out these wells and the existing well water is in contact with atmosphere for evaporation exchange of gases/ condensation/direct precipitation etc) and for D and Oxygen-18 sampling due to the effect of evaporation. If the samples are to be stored for longer period (> few months), these should be sealed with wax and stored at low temperature (4°C). The samples can be stored for more than a year without any treatment and preservation.

3.5. BASIC NOTION DURING TECHNIQUE APPLY:

IN NIH:-

3.5.1. FOR O₁₈ ANALYSIS:-

- Sample Volume: 300 μ L.
- Catalyst: Nil.
- Reference Gas: CO₂.
- Secondary Standards Used: 03 Bisleri, Gangotri & Sea Water.
- Total Number of samples in a batch: 60 Nos.
- Total Number of unknown samples in a batch: 46 Nos.
- Secondary Standards in a Batch: 14 Nos.
- Positions of Bisleri Standards: 1, 2, 15, 30, 45 & 60.
- Positions of Gangotri Standards: 5, 20, 35 & 50.
- Positions of Sea Water Standards: 10, 25, 40 & 55.
- Sample Bed Temperature: 40 °C.
- Equilibration Time: 07 Hrs.
- Calibration Method: 3 Point Calibration.
- Data Compilation: Multiple: Batch report wise, Appending in Total Analysis & Project wise.
- Analysed Data Storage: In multiple computers.

3.5.2. FOR H₂ ANALYSIS:-

- Sample Volume: 300 μ L.
- Catalyst: Hokko Coils that contains Platinum balls.
- Reference Gas: H₂
- Secondary Standards Used: 03 Bisleri, Gangotri & Sea Water.
- Total No. of samples in a batch: 60 Nos.
- Total No. of unknown samples in a batch: 46 Nos.
- Secondary Standards in a Batch: 14 Nos.
- Positions of Bisleri Standards: 1, 2, 15, 30, 45 & 60

- Positions of Gangotri Standards: 5, 20, 35 & 50.
- Positions of Sea Water Standards: 10, 25, 40 & 55
- Sample Bed Temperature: 40 °C.
- Equilibration Time: 03 Hrs.
- Calibration Method: 3 Point Calibration.
- Data Compilation: Multiple: Batch report wise, Appending in Total Analysis & Project wise.
- Analysed Data Storage: In multiple computers.

3.6 MEASUREMENT TECHNIQUE:

3.6.1 MASS SPECTROMETER:

Mass spectrometry (MS) is an analytical technique that ionizes chemical species and sorts the ions based on their mass-to-charge ratio. In simpler terms, a mass spectrum measures the masses within a sample.

3.6.1.1. PRINCIPLE OF MS:

A mass spectrometer generates multiple ions from the sample under investigation, it then separates them according to their specific mass-to-charge ratio (m/z), and then records the relative abundance of each ion type.

The basis of MS is to bend a beam of charged molecules in a magnetic field into a spectrum of masses.

The first step in the mass spectrometric analysis of compounds is the production of gas phase ions of the compound, basically by electron ionization. This molecular ion undergoes fragmentation. Each primary product ion derived from the molecular ion, in turn, undergoes fragmentation, and so on. The ions are separated in the mass spectrometer according to their mass-to-charge ratio, and

are detected in proportion to their abundance. A mass spectrum of the molecule is thus produced. It displays the result in the form of a plot of ion abundance versus mass-to-charge ratio. Ions provide information concerning the nature and the structure of their precursor molecule. In the spectrum of a pure compound, the molecular ion, if present, appears at the highest value of m/z (followed by ions containing heavier isotopes) and gives the molecular mass of the compound. The beam of charged molecules is usually generated by ionizing a gaseous sample at the ion source. A heated tungsten-coated iridium filament, inside the ion source block cavity, ionizes a laminar stream of gas entering the ultra-high vacuum source.

The gas molecules are stripped off one electron by the electron impact, producing positive ions (e.g. CO_2^+) that are then accelerated through a voltage gradient and focused into the flight tube upon exiting the source. Positively charged molecules obtain the velocity as, $[\frac{1}{2}mv^2 = Ev \text{ (1)}]$, where 'm', 'v', 'e' and 'V' represent mass of the charged molecules, obtained velocity, electrical charge and accelerating voltage, respectively.

The ionization efficiency varies between 0.01 and 0.1 % for different instruments. The ion beam bends as it passes through the field of a magnet installed over the flight tube. Here, the beam separates into a spectrum of masses according to the isotopes present as

$$mv^2/r = Hev \text{ (2)}$$

Where 'r' and 'H' represent curvature radius of the ion orbit and the force of magnetic field, respectively. Using eqn (1) and eqn (2), obtained

$$m/e = r^2H^2/2V$$

This eqn gives the mass of the ion. When the force of magnetic field 'H' and accelerating voltage 'V' are held constant, curvature radius 'r' is only varied with mass of the ion.

Each mass beam continues to the ion detectors where preset faraday cup collectors measure each ion current. By collecting two or three ion beams simultaneously, the ion current can be expressed in mass ratios. CO_2 would contribute three principal peaks at mass 44 ($^{12}\text{C}^{16}\text{O}_2$), 45 ($^{13}\text{C}^{16}\text{O}_2$ or $^{12}\text{C}^{17}\text{O}^{16}\text{O}$) and 46 ($^{12}\text{C}^{18}\text{O}^{16}\text{O}$). H_2 would contribute two principal peaks at mass 2 ($^1\text{H}^1\text{H}$) and 3 ($^2\text{D}^1\text{H}$). A dual-inlet system allows the mass spectrometer to measure ratios in the sample and the reference alternately. Thus, the extreme fractionation imparted during ionization in the source is resolved.

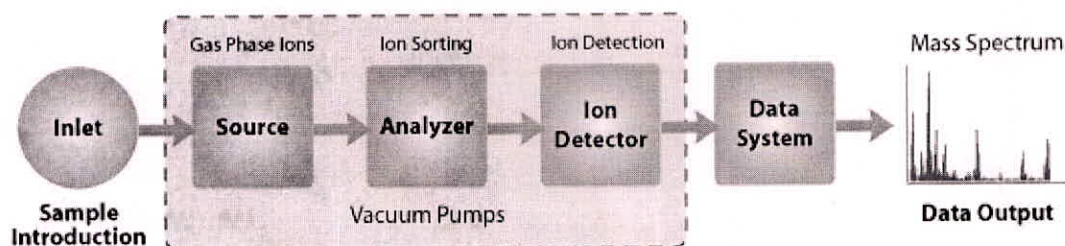


Figure 3.1.: Components of a Mass Spectrometer from inlet source to the data output.

3.6.1.2. Instrument Description

All mass spectrometer instruments have three basic parts: an ion source, a mass analyser, and ion collectors.

3.6.1. 2.1. Ion source:

The ion source is a small chamber in which reference and sample gas molecules are ionized by collisions with electrons. 1 molecule in 1000 is ionized to a positive ion, so ionization efficiency is low.

Presently, ion sources are based on the original Nier design (Nier, 1940, 1947). The electrons are emitted by thermal excitation from an incandescent wire filament, and then accelerated through the source by a voltage between the filament and source of 50-100 eV. The electrons are collimated by a narrow electron entrance slit opposite the filament, and then follow a helical path through the source under the influence of a magnetic field. The magnetic field is produced by two small permanent magnets. The field raises the ionization efficiency by increasing the probability of collisions between gas molecules and electrons.

The majority of electrons are not involved in ionization, and are collected at the trap, giving rise to a trap current. The current through the trap is used in a feedback loop to control the emission from the filament via the filament current. This is known as a trap-regulated system, and provides a constant flow of electrons through the source and, hence, a stable ion current into the analyser.

3.6.1.2.2. Analyser:

An analyser is a flight tube/magnet and has the ability to separate ions. The ion beam bends when it passes through the field of a magnet installed over the flight tube. Here, the beam separates into spectrum of masses according to the isotopes present and described by the equation (the details of the equation is given in the principle of mass spectrometry)

$$m/e = H^2 r^2 / 2V$$

The analyser housing is manufactured from stainless steel. The grade of steel ensures that the remnant magnetic fields within the analyser are low.

The housing is rectangular in section with two end flanges sealed with Viton. The end flanges carry the source and collectors. The flight tube is constructed from 1mm thick stainless steel plate, and is integrated into a cut-out in the side of the housing.

Baffles are fixed within the analyser to restrict unwanted ions from reaching the collectors. The baffles are readily removable for cleaning during normal maintenance. The design of the integrated flight tube in the housing provides an unobstructed focal plane which allows a number of masses to be measured simultaneously.

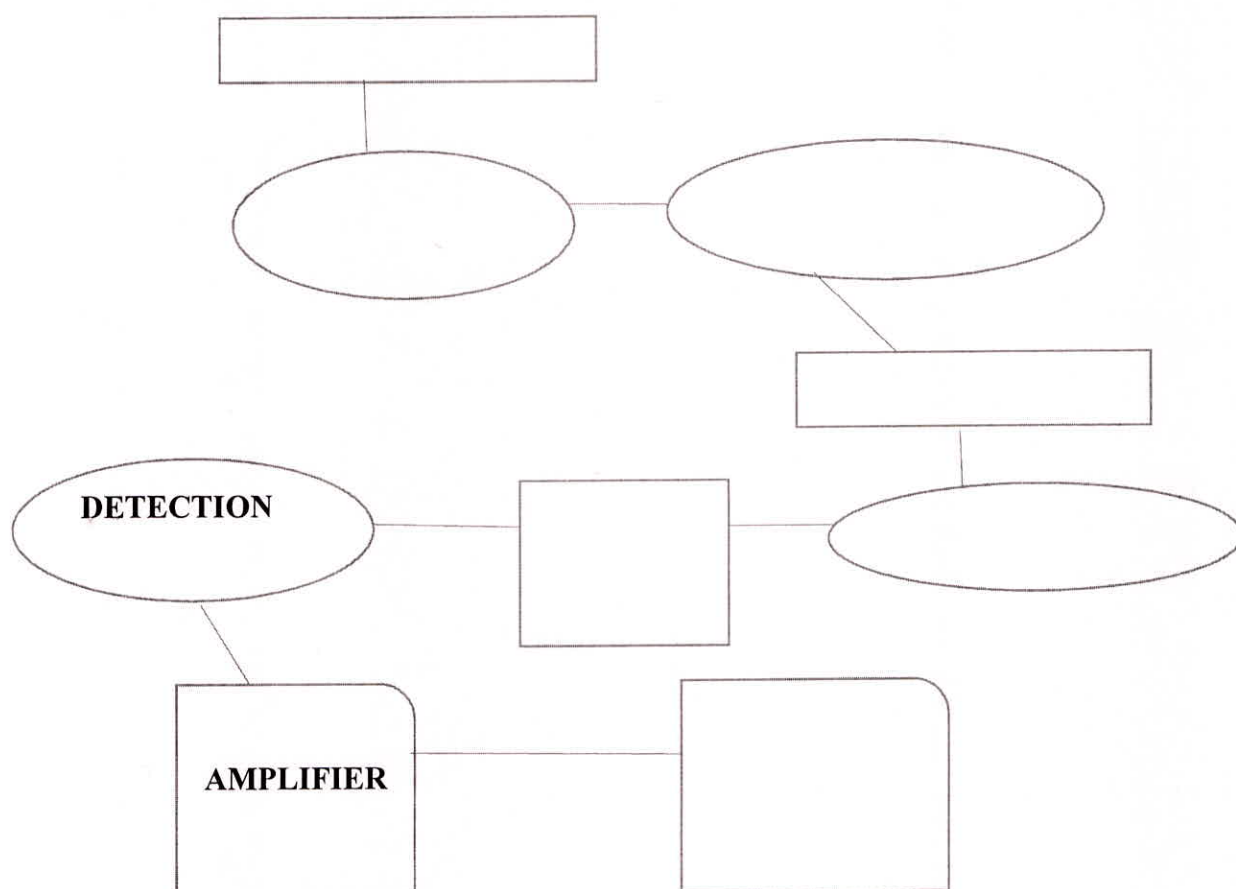
3.6.1.2.3. Ion collector:

After the ions are formed and separated according to their m/e values, the ion beams are detected by the Faraday cups. The universal collector consists of three Faraday cups, each with a different width of resolving slit.

With present designs, each separated ion beam is collected in an individual Faraday cup. These are long, narrow metal tubes to prevent ions, or the secondary electrons they produce

By collecting two or three ion beams simultaneously, the ion current can be expressed in mass ratios.

Figure 3.2. : A flow chart of mass spectrometer showing stepwise process in the inner instrument.



3.6.2. DUAL INLET MASS SPECTROMETER:

The basic principle of dual inlet IRMS is a comparison between sample and reference gases. Dual inlet consists of two identical halves: one for the sample gas and one for the reference.

An automated dual inlet equalizes sample and reference gas pressures, and hence their major ion beam currents, by adjusting the volumes of two storage reservoirs.

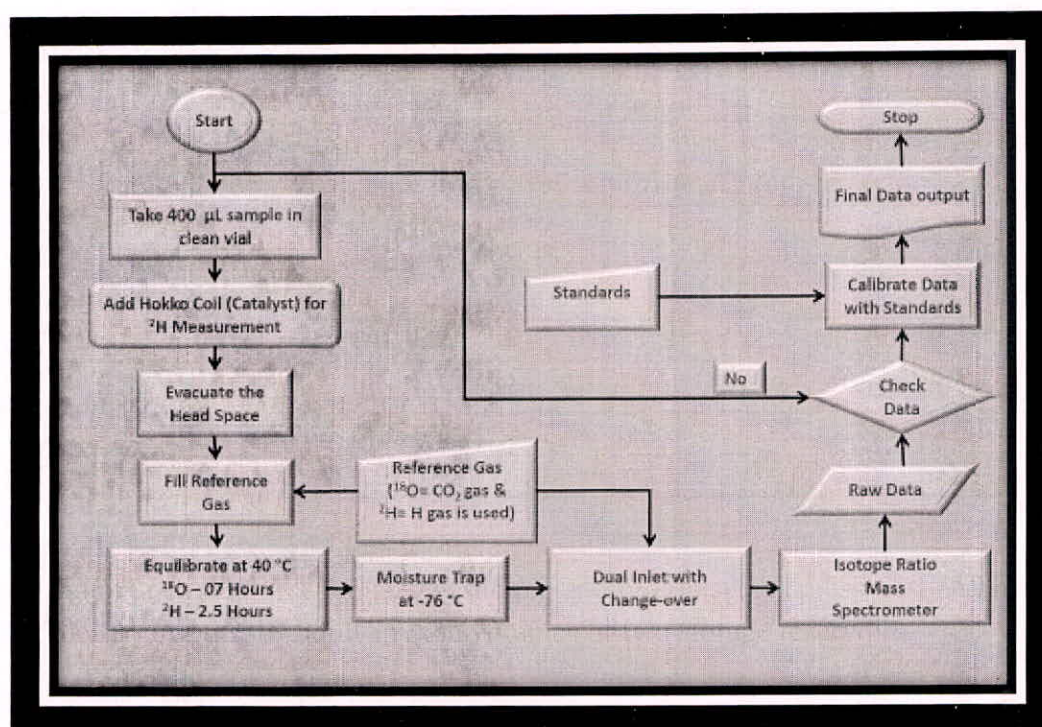


Figure 3.3: A flow chart of dual inlet isotope ratio mass spectrometer for the analysis of stable isotopes.

3.6.2.1. WORKING PRINCIPLE OF DUAL INLET:

Dual inlet mass spectrometers designed for the purpose of analysing gas samples and were first built in the 1940s. A schematic diagram of a typical dual inlet mass spectrometer is shown in **Fig.(3.4)**. There are two identical inlets, one containing a sample gas of unknown isotopic composition and one containing a reference gas. Each inlet consists of a variable volume, a cold finger, and a capillary crimped near to its termination. Both inlets are connected to a changeover valve mounted in close proximity to the ion source of the mass spectrometer, which is pumped to a 'background pressure' of $\approx 10^{-10}$ Torr (10^{-8} Pa; 10^{-13} Torr 133 Pa). Sample and reference gases, stored at relatively high pressures in each of the inlets, flow continuously through the capillaries and into the changeover valve. At the end of each capillary a crimp allows fine-scale adjustment of flow rate (a procedure carried out only once, when the instrument is first commissioned). The changeover valve selects one of the

gases for entry to the mass spectrometer, resulting in a typical 'source pressure' of 10^{-6} – 10^{-7} Torr ($\sim 10^{-4}$ – 10^{-5} pa), while the other gas flows to waste.

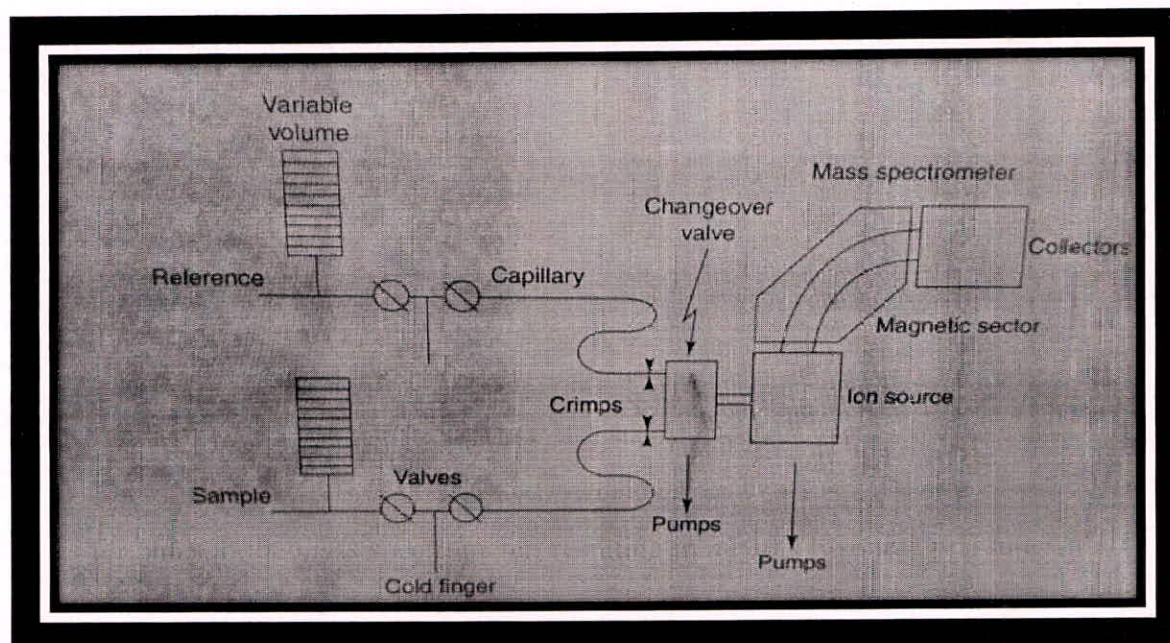


Figure 3.4.: A rough sketch to show the step by step process in dual inlet.

Source of 'closed' design, whereby the flowing gas is admitted to a small box in the mass spectrometer ion source (the ion source is not completely closed; a small conductance to the pump ensures an equilibrium pressure is reached as gases flow into the device). This arrangement results in a greater sensitivity of the instrument since a localized high pressure is obtained in the ion source, which in turn results in more intense ion beams. Too high a source pressure can result in an unwanted ion–molecule reaction, producing the H_3^+ ion, which causes interference at the masses detected during hydrogen isotope ratio measurement. In this case, it may be necessary to employ an ion source of more traditional, 'open' design, or to decrease the flow rate.

A schematic diagram of an ion source is shown in **Fig (3.5)**. Regardless of type (open or closed), the ionizing electrons are provided by a heated filament, generally tungsten, or thoriated–iridium coated on tungsten. A 3–5 A current boils electrons off the filament by thermionic emission, which are drawn into the ion source by a 60–80 V potential difference

between the filament and the rest of the ion source (referred to as the electron energy, typically 70 eV). A further voltage difference, between the ion source and the trap plate **Fig (3.5)**, produces a partially collimated electron beam. Electronic circuitry ensures that the trap current remains at a constant, preselected value (typically 100–1000 mA). Thus, any changes in filament current due to aging, or the effect of gas being admitted to the ion source, are counteracted by the preservation of a constant trap current. Small magnets produce a magnetic field parallel to the direction of the electron beam, increasing the effective path length by causing the electrons to spiral. The ion source is operated at a positive voltage of 2–5 kV above the ground potential. Thus, when an electron interacts with a neutral gas molecule and produces a positively charged ion this is ejected from the ion source and subsequently enters the magnetic field region of the mass spectrometer.

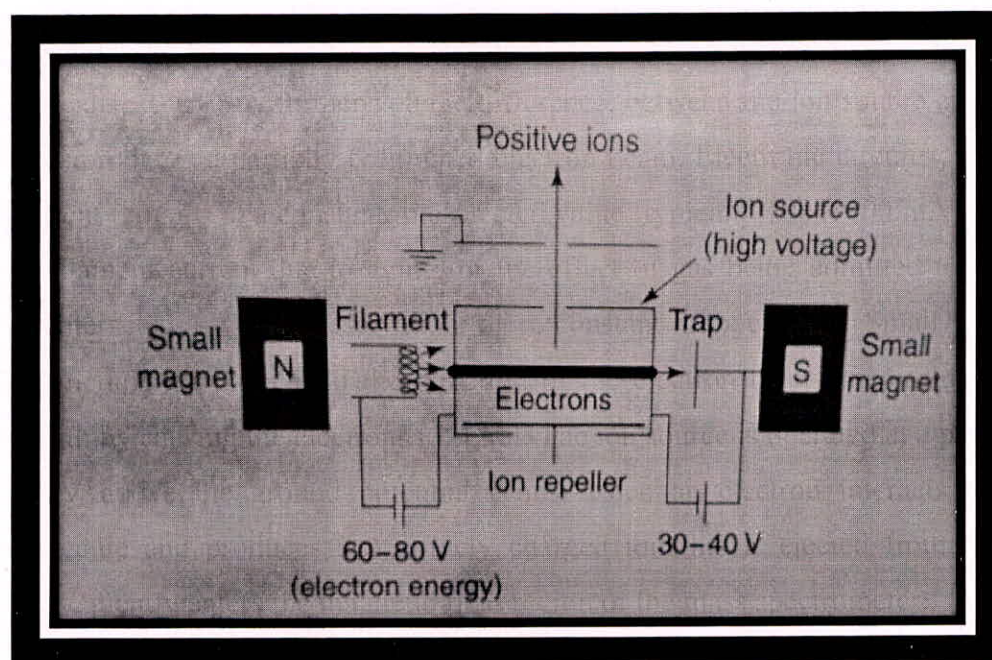


Figure 3.5.: Figure shows the flow from ion source to further trap plate.

An isotope ratio measurement is derived from a determination of the relative intensities of the ion beams as registered at the collectors or detector(s). Since the ion beams are due to nuclides that differ in mass by approximately one, the mass resolution does not need to be greater than B100 Da. Thus, stable isotope ratio mass spectrometers are generally small, comprising a magnet that produces a flight path of the ions of the order of 6–12 cm radius, with a deflection angle of 60° or 90°. Typical ion beam intensities are generally greater than

10^{-12} A; therefore, stable isotope ratio mass spectrometers do not require high-gain devices such as electron multipliers. Faraday bucket-type detectors referred to normally as a 'collector' are sufficient. Almost all stable isotope ratio mass spectrometers are fitted with multiple collectors capable of measuring the desired ion beams simultaneously.

The use of multiple collectors reduces the analysis time and circumvents the problem of instability in the instrument following a 'peak jumping' routine, whereby the ion beams of interest are successively focused onto a single collector (i.e., by changing the magnitude of the accelerating voltage, or the magnetic field strength). Some older stable isotope ratio mass spectrometers intended for carbon dioxide analysis may only have two collectors although there are three ion beams that need to be detected. In this case it is necessary to peak-jump in order to measure the appropriate ion beam ratios, which results in a doubling of the analysis time and, correspondingly, isotope ratio measurements that are not as precise as those obtained from instruments with three collectors. Stable isotope ratio instruments are intended for the analysis of individual, uncomplicated gas species, such as carbon dioxide. Thus, as long as the less intense (minor) beams are adequately focused and collected, the major ions can essentially just be directed toward a wide collector (i.e., the each detector is connected to a high-gain amplifier mounted immediately outside the high-vacuum chamber of the mass spectrometer. In sophisticated designs these amplifiers are mounted in their own vacuum chamber (at $\sim 10^{-3}$ Torr), which helps to stabilize the environmental conditions surrounding the amplifiers and reduces instability in the measured ion beam signal. The amplifiers convert the small ion currents into dc voltages (~ 0.1 – 10 V), which can then be further amplified if necessary, processed by an analogy-to-digital converter, and read into a desktop computer.

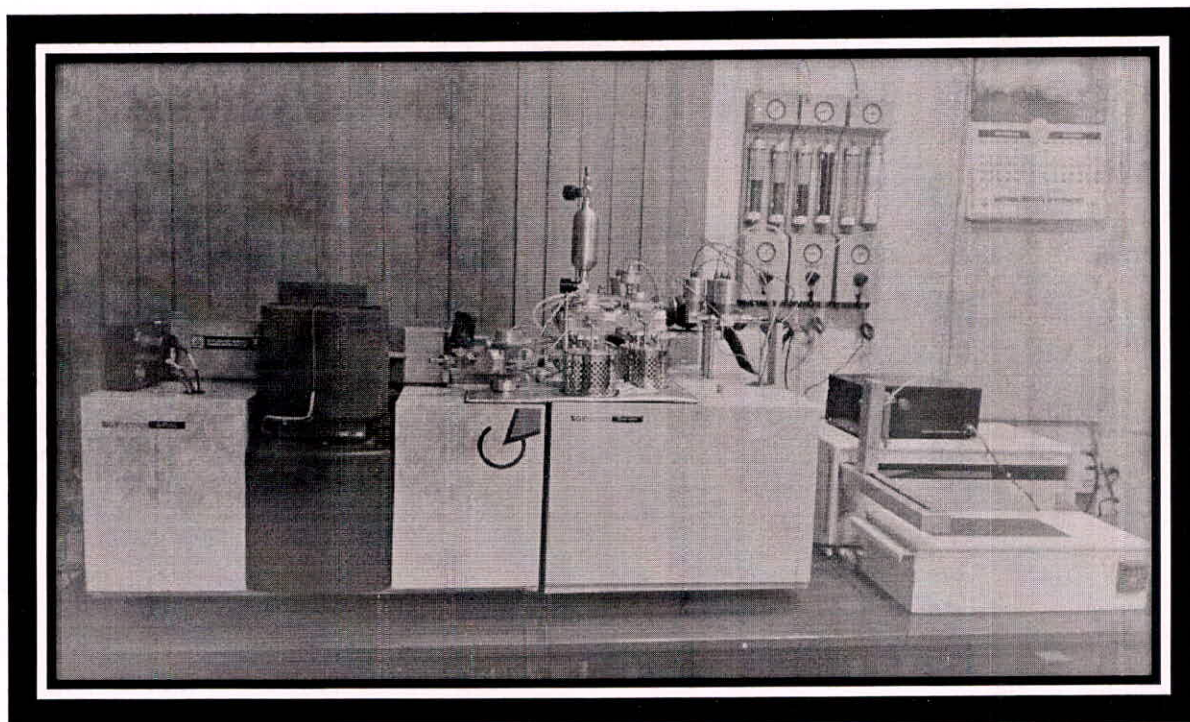


Figure 3.6: Full overview structure of dual inlet IRMS.

3.6.3. ION CHROMATOGRAPHY:

Ion: an atom or a group of atoms that has either an excess or a deficiency of electrons. major ions in water, positive charge (cations), negative charge (anions): H^+ , Na^+ , K^+ , Ca^{2+} , Mg^{2+} , OH^- , Cl^- , SO_4^{2-} , NO_3^- , HCO_3^- , PO_4^{3-} .

“Ion exchange chromatography may be defined as the reversible exchange of ions in the solution with ions electrostatically bound to some sort of insoluble matrix or a stationary phase”. M. Tswett (1872-1919), a Russian botanist, discovered chromatography in 1901 during his research on plant pigments. It is a process that allows the separation of ions and polar molecules based on their charge.

An ion chromatography system typically consists of a liquid eluent, a high-pressure pump, a sample injector, a guard and separator column, a chemical suppressor, a conductivity cell, and a data collection system. Before running a sample, the ion chromatography system is calibrated using a standard solution. By comparing the data obtained from a sample to that

obtained from the known standard, sample ions can be identified and quantitated. The data collection system, typically a computer running chromatography software, produces a chromatogram (a plot of the detector output vs. time). The chromatography software converts each peak in the chromatogram to a sample concentration and produces a printout of the results.

3.6.3.1. HOW IT WORK:

- A sample of the mixture to be analysed (analyte) is injected into a carrier fluid (the eluent).
- The combination is passed through a column containing a stationary fixed material (adsorbent).
- Compounds contained in the analyte are then partitioned between the stationary adsorbent and the moving eluent/analyte mixture.
- Different dissolved materials adhere to the adsorbent with different forces.
- The ones that adhere strongly are moved through the adsorbent more slowly as the eluent flows over them.
- As the eluent flows through the column the components of the analyte will move down the column at different speeds and therefore separate from one another.
- A detector is used to analyse the output at the end of the column. There are various detectors, our IC has an electrical conductivity detector.
- Each time analyte molecules/ions emerge from the chromatography column the detector generates a measurable signal which is usually printed out as a peak on the chromatogram.
- A suppressor is being used to reduce the background conductance of the Eluent and at the same time enhance the conductance of the sample ion.

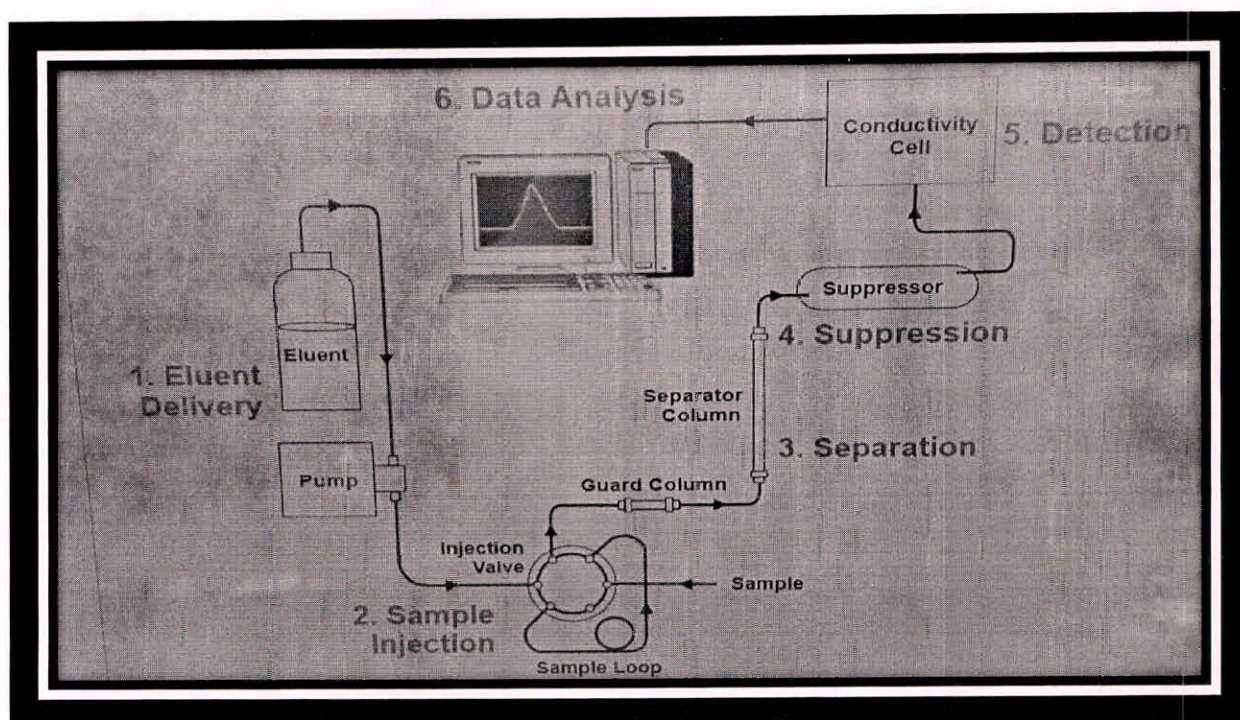


Figure 3.7: The full system through it work and through which path it goes in ion chromatography.

3.6.3.2. DISCRIPTION OF THE ABOVE PATH:

3.6.3.2.1. Eluent Delivery -

- Eluent, a liquid that helps to separate the sample ions, carries the sample through the ion chromatography system. The Dionex includes an eluent generator, which generates eluent online from deionized water.
- When the Dionex is controlled from the front panel, only isocratic eluent delivery is possible. This means that the eluent composition and concentration remain constant throughout the run. Gradient delivery (a change in concentration over time) is possible when the Dionex is controlled by Chromeleon™ ChromatographyManagement System (the data collection system for the Dionex).

3.6.3.2.2. Sample Injection-

- The liquid sample is loaded into a sample loop either manually or automatically (if an automated sampler is installed). When triggered, the Dionex injects the sample into the eluent stream.
- The pump pushes the eluent and sample through the guard and separator columns (chemically-inert tubes packed with a polymeric resin). The guard column removes contaminants that might poison the separator column.

3.6.3.2.3. Separation-

- As the eluent and sample are pumped through the separator column, the sample ions are separated. In the Dionex, the mode of separation is called ion exchange. This is based on the premise that different sample ions migrate through the IC column at different rates, depending upon their interactions with the ion exchange sites

3.6.3.2.4. Suppression-

- A conductivity cell measures the electrical conductance of the sample ions as they emerge from the suppressor and produces a signal based on a chemical or physical property of the analyte.

3.6.3.2.5. Data Analysis-

- The conductivity cell transmits the signal to a data collection system.

- The data collection system (for the Dionex, this is the Chromeleon™ Chromatography Management System) identifies the ions based on retention time, and quantifies each analyte by integrating the peak area or peak height. The data is quantitated by comparing the sample peaks in a chromatogram to those produced from a standard solution. The results are displayed as a chromatogram and the concentrations of ionic analytes can be automatically determined and tabulated.

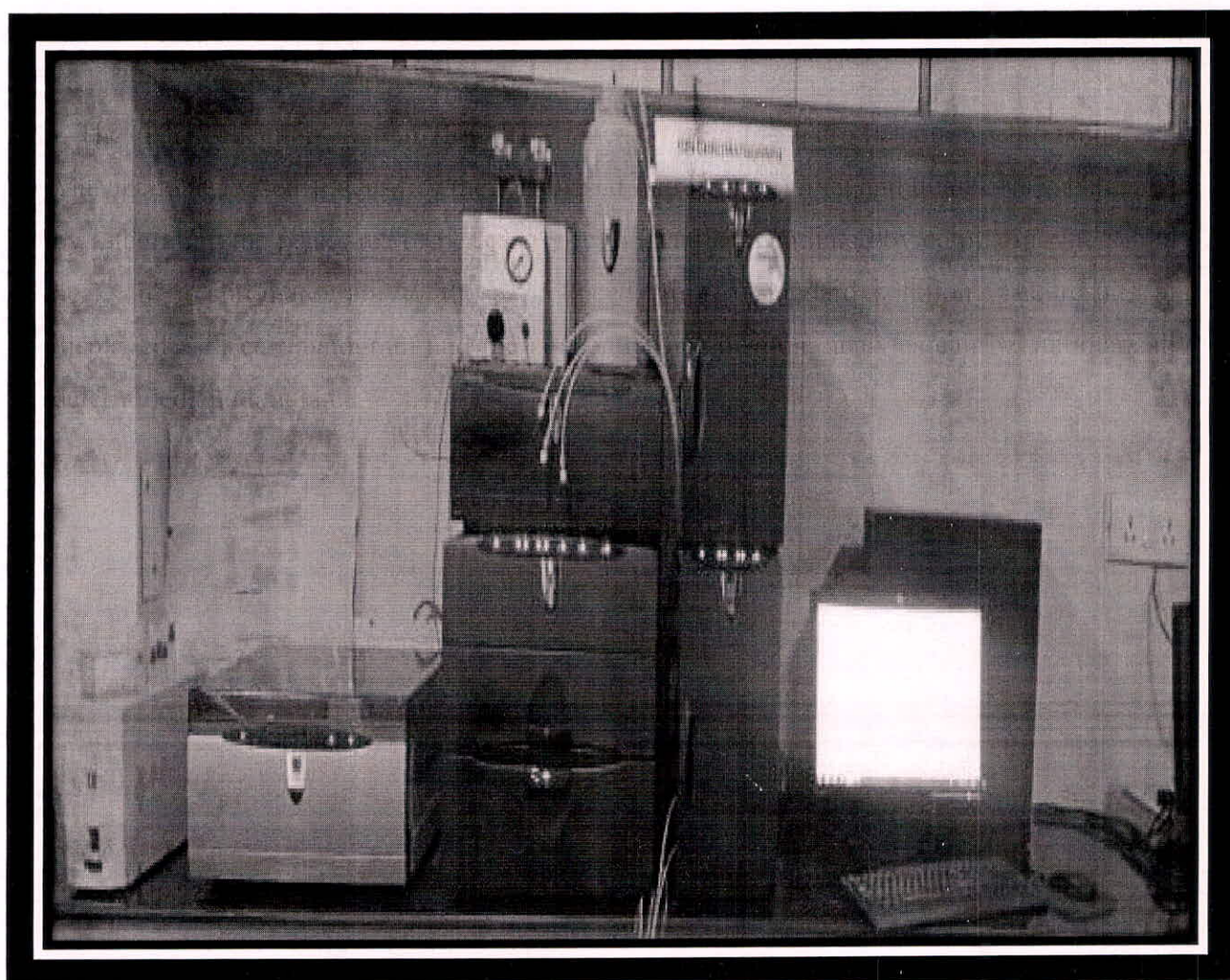


Figure 3.8: Figure showing all the components along with the system of data analysis.

3.7. GIS (GEOGRAPHIC INFORMATION SYSTEM):

A geographic information system is a computer system for capturing, storing, checking and displaying data related to positions on earth's surface. GIS shows many different kinds of data on the map. In this study, GIS provide the basic outline of the districts of coastal zones of Andhra Pradesh which is being used to allocate the zone of sampling.

.This shp file is then digitized in the SURFER to get the coastline of the Andhra Pradesh.

3.8. SUMMARY:

This chapter has given the idea about the methodologies that is applied in the report to get the objective of the study. To get the objective these are the techniques which is followed. And in the next chapter the results of this techniques is displayed.

CHAPTER 4

4.1. RESULTS AND DISCUSSION:

GENERAL:

As the samples has collected from the coastal zone of Andhra Pradesh and in month of May to June. The zone from where the samples are collected from north to south, Srikakulam to Nellore. In this chapter, the values of both the techniques are evaluated and the ion balancing is done, type of water in the areas or in sampling locations are done by the piper diagram and the hypothesis of Cl^- , O_{18} and the distance from the coast.

4.2 ABOUT FIRST PHASE OF EXPERIMENT:

The first phase includes the analysis of EC, Temperature, pH, and radon after the collection of samples.

Table 4.1. Showing the results of EC, temperature and pH.

Site ID	Date	Source	EC	Temp	pH	Rn(pCi/L)
SGD-54	31-05-2016	HP	2600	29.9	7	314.27
SGD 56	31-05-2016	HP	2400	30.1	7	180.77
SGD 57	31-05-2016	HP	490	29.6	6.9	99.14
SGD 58	01-06-2016	HP	1180	30.5	7.2	57.41
SGD 59	01-06-2016	HP	1100	31	7.4	77.92
SGD 60	01-06-2016	HP	1830	30.2	7.2	302.76
SGD 61	01-06-2016	HP	2700	30.8	7.1	448.61

SGD 62	02-06-2016	HP	3300	31	7.5	85.7
SGD 63	02-06-2016	HP	2600	32	7.3	57.71
SGD 64	02-06-2016	HP	2600	30	7.2	133.74
SGD 65	02-06-2016	HP	940	29.7	7.8	28.16
SGD 66	02-06-2016	HP	1430	29.4	7.1	35.69
SGD 67	03-06-2016	HP	4000	29.6	7	40.96
SGD 68	03-06-2016	HP	840	28.9	7.2	26.72
SGD 69	03-06-2016	HP	2100	28.2	7.1	22.48
SGD 70	04-06-2016	HP	2300	29.9	7.5	41.86
SGD 71	04-06-2016	HP	2600	32.6	7.2	44.85
SGD 74	05-06-2016	HP	1120	30.8	7.6	46.51
SGD 76	05-06-2016	HP	6100	31.2	6.9	433.02
SGD 77	05-06-2016	HP	1480	31.6	7.3	249.28
SGD 78	05-06-2016	HP	3100	30.3	7.7	125.75
SGD-79	06-06-2016	HP	8400	31.1	7.1	74.61
SGD-80	06-06-2016	HP	2500	30.3	7.6	102.33
SGD-81	06-06-2016	HP	790	30.5	7.2	169.78
SGD-82	06-06-2016	HP	3400	29.6	7.2	175.28
SGD-83	07-06-2016	HP	3400	30.4	7.6	25.16
SGD-84	07-06-2016	HP	5900	29.6	7.2	15.84
SGD-86	07-06-2016	HP	1780	30.6	7.4	13.78
SGD-87	07-06-2016	HP	870	30.2	7.5	31.79
SGD-88	07-06-2016	HP	740	29.8	7.4	30.41
SGD-89	08-06-2016	HP	760	29.8	7.3	28.66
SGD 90	08-06-2016	HP	890	31.1	7.5	19.77
SGD-91	08-06-2016	HP	700	29.7	7	24.38
SGD-92	08-06-2016	HP	880	29.7	7.1	125
SGD-94	09-06-2016	HP	1010	30.7	7.3	38.5
SGD-95	09-06-2016	HP	740	31.6	7.3	71.56
SGD-96	09-06-2016	HP	710	30.5	7.3	77.51
SGD-98	10-06-2016	HP	620	33.3	7.5	83.96
SGD-101	10-06-2016	HP	720	31.3	7.5	168.57

SGD-102	10-06-2016	HP	700	31.8	7.6	187.92
SGD-103	10-06-2016	HP	760	30.7	7.5	143.83
SGD-104	11-06-2016	HP	720	32	7.5	51.9
SGD-105	11-06-2016	HP	740	31.1	7.5	113.46
SGD-106	11-06-2016	HP	770	32.6	7.4	90.88
SGD-107	11-06-2016	HP	860	31.2	7.1	143.61

Table 4.2. Showing maximum, minimum and average values for EC, pH, temperature & radon.

PARAMETERS	MINIMUM & MAXIMUM CONCENTRATION & THE OBSERVED PLACE.		
	MINIMUM	Maximum	Average
EC ($\mu\text{S}/\text{cm}$)	490 (Baruva, Dist: Srikakulam))	8400 (S. Yanam)	1875.82
Temp($^{\circ}\text{C}$)	28.2 $^{\circ}\text{C}$ (Chapala Kancheru)	33.3 $^{\circ}\text{C}$ (ThatichetlaPalem)	30.58
Radon(pci/l)	13.78 pCi/L (MutyalapalliModi, Kallipatnam, Palkol)	448.61 pCi/L (Bendigate)	106.51
pH	6.9 (Baruva, Sungvruksham Nr Thondangi Rd, Patalkodada,	7.8 (KunduVaniPeta	7.31

	Kothapalle)	beach)	
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About the results of the above samples the sampling location SGD 57, SGD 69 , SGD 86 and SGD 75 are having minimum EC, Temperature, radon and pH, SGD 79, SGD 98 , SGD 61 and SGD 65 has the maximum of the following. And after the evaluation it has examined that the average of the above mentioned parameters are 1875.82, 30.58, 106.51 and 7.31 respectively.

Table 4.3. Showing all the cations and anions for ion balancing.

Site ID	Date	Source	Fluoride	Chloride	Nitrite	Sulfate	Nitrate	Sodium	Ammonium	Potassium	Magnesium	Calcium	HCO3
SGD-54	31-05-2016	HP	0.80	197.53	10.68	26.52	79.71	123.82	4.28	80.97	29.37	102.32	488
SGD 56	31-05-2016	HP	ND	391.47	25.55	83.80	14.69	285.06	4.59	37.80	62.00	119.71	854
SGD 57	31-05-2016	HP	0.22	211.76	8.92	68.71	88.46	273.21	1.92	32.62	22.47	58.74	122
SGD 58	01-06-2016	HP	ND	84.51	13.79	9.63	29.90	71.56	2.16	3.45	14.95	123.39	854
SGD 59	01-06-2016	HP	0.59	90.22	12.91	16.67	63.72	103.73	2.04	19.47	26.71	86.40	463.6
SGD 60	01-06-2016	HP	1.49	210.37	28.97	23.76	0.41	296.88	7.54	5.63	52.05	74.21	1220
SGD 61	01-06-2016	HP	ND	365.15	35.51	27.40	ND	434.40	3.25	4.75	74.77	89.79	1220
SGD 62	02-06-2016	HP	1.88	481.86	29.21	72.87	181.94	588.80	ND	56.94	60.76	87.78	488
SGD 63	02-06-2016	HP	ND	395.79	31.49	61.04	49.86	297.19	ND	5.78	136.11	110.43	976
SGD 64	02-06-2016	HP	0.72	297.26	38.25	106.43	56.04	449.13	8.69	12.93	80.46	107.28	1342
SGD 65	02-06-2016	HP	0.21	132.07	12.01	4.51	ND	110.12	1.80	6.53	38.16	39.38	366
SGD 66	02-06-2016	HP	1.15	153.92	16.22	127.06	19.64	177.21	ND	18.79	51.88	110.60	549
SGD 67	03-06-2016	HP	ND	488.77	37.43	82.48	202.18	562.50	3.64	88.79	76.98	198.73	488
SGD 68	03-06-2016	HP	0.88	18.31	20.58	1.46	ND	70.87	1.15	2.59	22.55	59.38	579.5
SGD 69	03-06-2016	HP	ND	198.90	26.06	37.53	94.00	235.91	1.74	53.83	59.24	109.88	549
SGD 70	04-06-2016	HP	ND	346.26	30.10	75.93	101.97	322.33	4.32	134.10	68.68	120.35	366
SGD 71	04-06-2016	HP	ND	160.80	9.11	65.30	5.41	155.47	1.78	4.40	47.43	42.67	567.3
SGD 72	04-06-2016	HP	0.47	28.06	14.62	9.18	ND	79.88	1.38	4.55	12.41	60.34	317.2
SGD 74	05-06-2016	HP	1.33	170.11	ND	35.52	100.67	158.08	1.48	8.29	52.96	133.45	488
SGD 76	05-06-2016	HP	ND	408.17	13.20	70.94	ND	306.30	2.06	5.41	69.61	78.55	854
SGD 77	05-06-2016	HP	ND	268.46	28.06	72.90	287.20	210.96	12.46	176.11	101.90	224.49	427
SGD 78	05-06-2016	HP	4.12	1353.62	87.49	100.52	ND	1763.41	10.22	74.47	89.63	91.84	854
SGD-79	06-06-2016	HP	ND	790.16	23.40	38.86	ND	655.02	7.40	36.72	73.08	40.35	1830
SGD-80	06-06-2016	HP	0.11	64.58	19.84	18.19	ND	177.15	6.09	45.42	10.23	86.76	1586
SGD-81	06-06-2016	HP	0.94	77.78	64.70	24.30	ND	165.46	14.57	67.55	116.28	244.36	793
SGD-82	06-06-2016	HP	1.83	695.89	33.60	29.60	3.76	574.05	14.47	34.42	81.83	135.06	854
SGD-83	07-06-2016	HP	12.27	1340.57	62.63	60.32	0.34	1074.40	22.69	56.62	143.96	129.81	732
SGD-84	07-06-2016	HP	3.06	1235.28	38.58	275.96	ND	1357.63	21.10	40.83	119.03	69.61	1647
SGD-86	07-06-2016	HP	0.53	108.12	9.63	51.90	7.42	108.06	7.13	26.40	32.07	49.15	732
SGD-87	07-06-2016	HP	ND	2077.98	20.44	2997.26	ND	1928.34	8.62	22.91	282.58	168.86	732
SGD-91	08-06-2016	HP	0.41	60.27	15.28	31.92	0.09	103.43	4.92	6.08	45.06	50.87	854
SGD-92	08-06-2016	HP	0.35	1823.08	46.27	311.54	62.51	1684.28	3.84	72.84	94.70	52.10	1830
SGD-95	09-06-2016	HP	ND	321.66	12.24	47.71	2.33	364.51	4.27	11.55	36.10	45.98	854
SGD-96	09-06-2016	HP	ND	216.59	9.93	127.71	11.01	203.97	4.19	21.70	45.50	89.21	732
SGD-97	09-06-2016	HP	ND	671.69	28.21	254.23	108.08	654.76	9.94	145.30	75.67	117.60	976
SGD-101	10-06-2016	HP	ND	311.30	14.53	128.01	215.78	351.45	6.75	167.07	60.04	126.86	732
SGD-102	10-06-2016	HP	ND	254.86	11.68	71.34	151.87	228.71	3.01	43.67	68.29	140.40	488
SGD-103	10-06-2016	HP	ND	621.09	19.97	152.94	209.36	655.31	8.23	114.06	50.95	167.70	488
SGD 104	11-06-2016	HP	ND	376.48	16.75	70.64	187.59	420.47	2.08	43.83	48.44	114.01	732
SGD 105	11-06-2016	HP	0.62	399.17	17.66	78.97	203.31	414.45	3.42	44.06	50.11	119.95	976
SGD 107	11-06-2016	HP	ND	2494.56	34.42	387.07	117.72	1482.09	4.56	104.73	183.15	229.30	488

HERE: ND (NOT DETECTED)

The summation of total cation and total anion and the subtraction of that gives the equivalent balance % which is evaluated in aquachem and the average of all the ions gives the % and thus in this report the error in sampling is about 5.916.

4.3 PIPER DIAGRAM:

A piper plot is a way of visualizing the chemistry of a rock, soil, or water sample. It's comprised of three pieces: a ternary diagram in the lower left representing the cations, a ternary diagram in the lower right representing the anions, and a diamond plot in the middle representing a combination of the two..

The diamond diagram tells about different things depending on what is the field of plotting. For example, for groundwater, the top quadrant is calcium sulphate waters (gypsum ground water and mine drainage), the left Quadrant is calcium bicarbonate waters (shallow fresh ground water), the right quadrant is sodium chloride waters (marine and deep ancient ground water), and the bottom quadrant is sodium bicarbonate waters (deep ground water influenced by ion exchange).

Table 4.4. The following chart depicts the sampling id from which samples have been collected and their data that is used in piper diagram [HERE – HP (HAND PUMP)].

Site ID	Fluoride	Chloride	Nitrite	Sulfate	Nitrate
SGD-54	0.80	197.53	10.68	26.52	79.71
SGD 56	ND	391.47	25.55	83.80	14.69
SGD 57	0.22	211.76	8.92	68.71	88.46
SGD 58	ND	84.51	13.79	9.63	29.90
SGD 59	0.59	90.22	12.91	16.67	63.72
SGD 60	1.49	210.37	28.97	23.76	0.41
SGD 61	ND	365.15	35.51	27.40	ND
SGD 62	1.88	481.86	29.21	72.87	181.94
SGD 63	ND	395.79	31.49	61.04	49.86
SGD 64	0.72	297.26	38.25	106.43	56.04
SGD 65	0.21	132.07	12.01	4.51	ND
SGD 66	1.15	153.92	16.22	127.06	19.64
SGD 67	ND	488.77	37.43	82.48	202.18
SGD 68	0.88	18.31	20.58	1.46	ND
SGD 69	ND	198.90	26.06	37.53	94.00
SGD 70	ND	346.26	30.10	75.93	101.97
SGD 71	ND	160.80	9.11	65.30	5.41
SGD 72	0.47	28.06	14.62	9.18	ND
SGD 74	1.33	170.11	ND	35.52	100.67
SGD 76	ND	408.17	13.20	70.94	ND
SGD 77	ND	268.46	28.06	72.90	287.20
SGD 78	4.12	1353.62	87.49	100.52	ND
SGD-79	ND	790.16	23.40	38.86	ND
SGD-80	0.11	64.58	19.84	18.19	ND
SGD-81	0.94	77.78	64.70	24.30	ND
SGD-82	1.83	695.89	33.60	29.60	3.76
SGD-83	12.27	1340.57	62.63	60.32	0.34
SGD-84	3.06	1235.28	38.58	275.96	ND
SGD-86	0.53	108.12	9.63	51.90	7.42
SGD-87	ND	2077.98	20.44	2997.26	ND
SGD-91	0.41	60.27	15.28	31.92	0.09
SGD-92	0.35	1823.08	46.27	311.54	62.51
SGD-95	ND	321.66	12.24	47.71	2.33
SGD-96	ND	216.59	9.93	127.71	11.01
SGD-97	ND	671.69	28.21	254.23	108.08
SGD-101	ND	311.30	14.53	128.01	215.78
SGD-102	ND	254.86	11.68	71.34	151.87
SGD-103	ND	621.09	19.97	152.94	209.36
SGD 104	ND	376.48	16.75	70.64	187.59
SGD 105	0.62	399.17	17.66	78.97	203.31
SGD 107	ND	2494.56	34.42	387.07	117.72

Table 4.5. And this table gives the values of cations and anions of the above mentioned samples: HERE- [ND says (NOT DETECTED)]

Site ID	Sodium	Ammonium	Potassium	Magnesium	Calcium	HCO ₃
SGD-54	123.82	4.28	80.97	29.37	102.32	488
SGD 56	285.06	4.59	37.80	62.00	119.71	854
SGD 57	273.21	1.92	32.62	22.47	58.74	122
SGD 58	71.56	2.16	3.45	14.95	123.39	854
SGD 59	103.73	2.04	19.47	26.71	86.40	463.6
SGD 60	296.88	7.54	5.63	52.05	74.21	1220
SGD 61	434.40	3.25	4.75	74.77	89.79	1220
SGD 62	588.80	ND	56.94	60.76	87.78	488
SGD 63	297.19	ND	5.78	136.11	110.43	976
SGD 64	449.13	8.69	12.93	80.46	107.28	1342
SGD 65	110.12	1.80	6.53	38.16	39.38	366
SGD 66	177.21	ND	18.79	51.88	110.60	549
SGD 67	562.50	3.64	88.79	76.98	198.73	488
SGD 68	70.87	1.15	2.59	22.55	59.38	579.5
SGD 69	235.91	1.74	53.83	59.24	109.88	549
SGD 70	322.33	4.32	134.10	68.68	120.35	366
SGD 71	155.47	1.78	4.40	47.43	42.67	567.3
SGD 72	79.88	1.38	4.55	12.41	60.34	317.2
SGD 74	158.08	1.48	8.29	52.96	133.45	488
SGD 76	306.30	2.06	5.41	69.61	78.55	854
SGD 77	210.96	12.46	176.11	101.90	224.49	427
SGD 78	1763.41	10.22	74.47	89.63	91.84	854
SGD-79	655.02	7.40	36.72	73.08	40.35	1830
SGD-80	177.15	6.09	45.42	10.23	86.76	1586
SGD-81	165.46	14.57	67.55	116.28	244.36	793
SGD-82	574.05	14.47	34.42	81.83	135.06	854
SGD-83	1074.40	22.69	56.62	143.96	129.81	732
SGD-84	1357.63	21.10	40.83	119.03	69.61	1647
SGD-86	108.06	7.13	26.40	32.07	49.15	732
SGD-87	1928.34	8.62	22.91	282.58	168.86	732
SGD-91	103.43	4.92	6.08	45.06	50.87	854
SGD-92	1684.28	3.84	72.84	94.70	52.10	1830
SGD-95	364.51	4.27	11.55	36.10	45.98	854
SGD-96	203.97	4.19	21.70	45.50	89.21	732
SGD-97	654.76	9.94	145.30	75.67	117.60	976
SGD-101	351.45	6.75	167.07	60.04	126.86	732
SGD-102	228.71	3.01	43.67	68.29	140.40	488
SGD-103	655.31	8.23	114.06	50.95	167.70	488
SGD 104	420.47	2.08	43.83	48.44	114.01	732
SGD 105	414.45	3.42	44.06	50.11	119.95	976
SGD 107	1482.09	4.56	104.73	183.15	229.30	488

Using all the above collected data which is obtained from the ion chromatography instrument that is being utilised in aquachem to derive the type of water in the Andhra Pradesh costal area.



Figure 4.1 Aquachem (2014):

All the above parameters values has been set in it to get the correct result. After getting the proper input of the data the piper diagram as well as the excel sheet of the data gets generated.

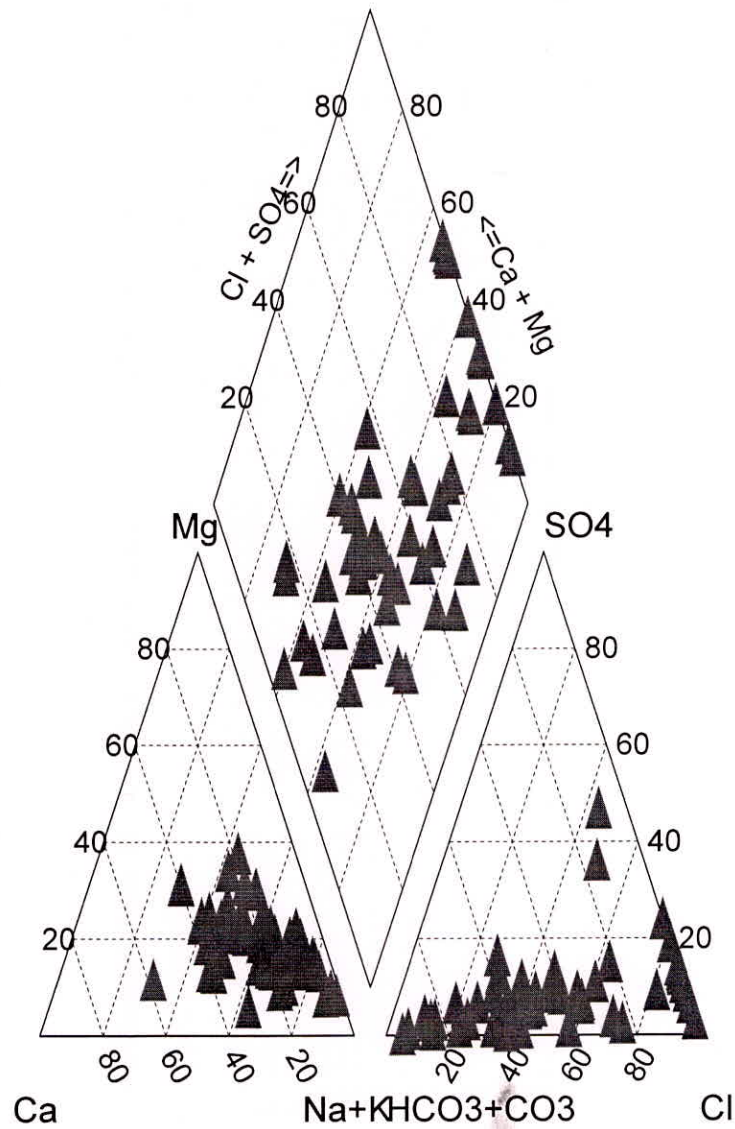


Figure 4.2. The figure shows the points in the piper diagram which is generated by putting all the chemistry values.

Legend A- Calcium type, B, H- No Dominant type, C- Magnesium type, D- Sodium and potassium type, E- Bicarbonate type, F- Sulphate type, G- Chloride type.

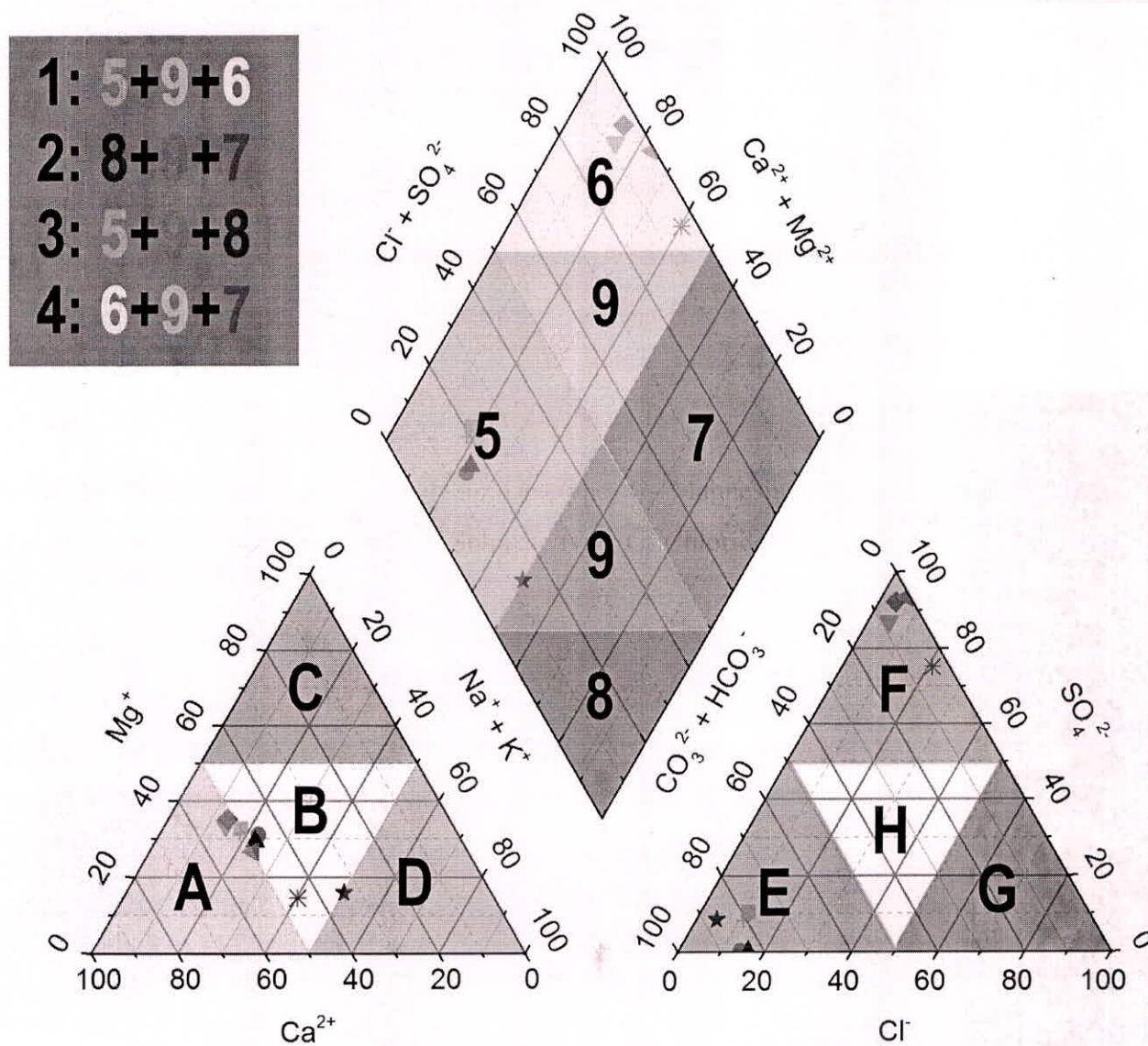


Figure 4.3. Basic idea when the samples lies in the zone.

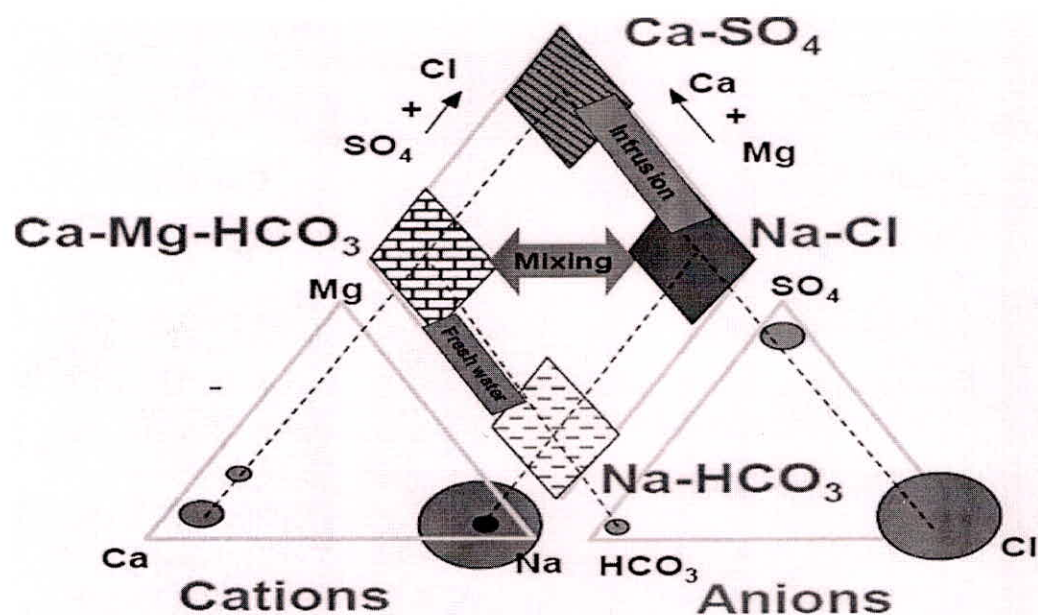


Figure 4.4. Area zone declaration given below in the diagram.

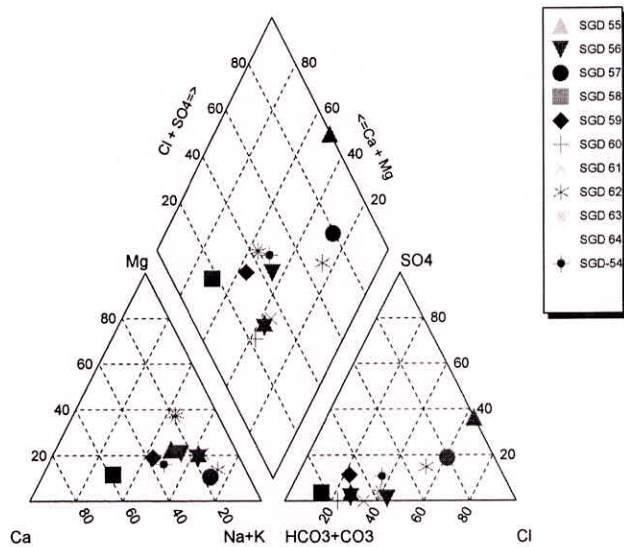
Table 4.6.- The excel sheet that has been generated gives the information like this:

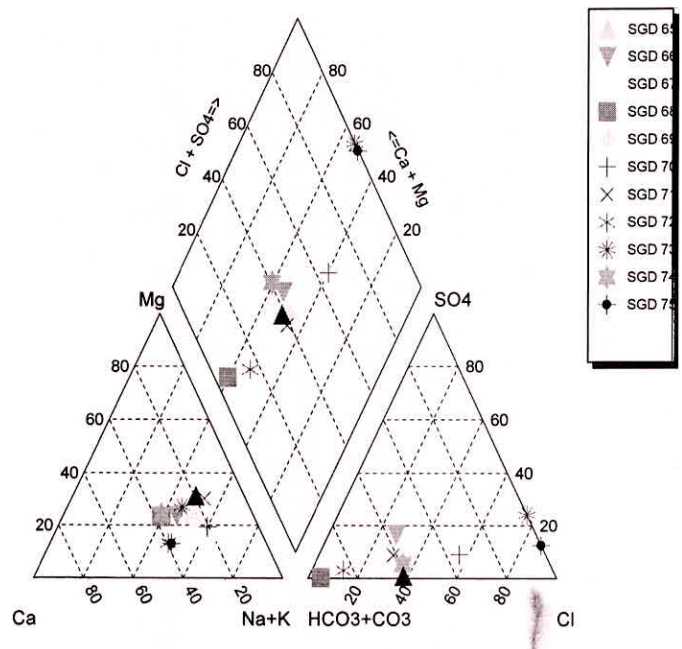
Source	Sample id	Water type
HP	SGD 54	Na-Ca-HCO ₃ -Cl
HP	SGD 55	Na-Ca-Mg-Cl-NO ₃
HP	SGD 56	Na-Ca-HCO ₃ -Cl
HP	SGD 57	Na-Ca-Cl
HP	SGD 58	Ca-Na-HCO ₃

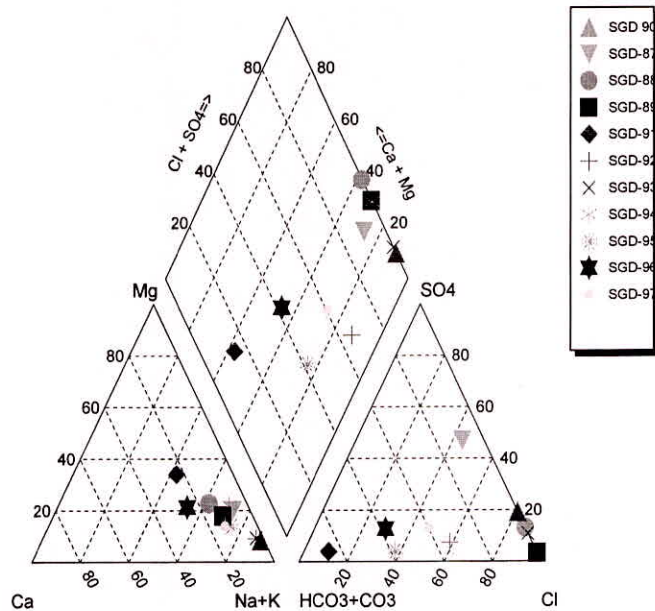
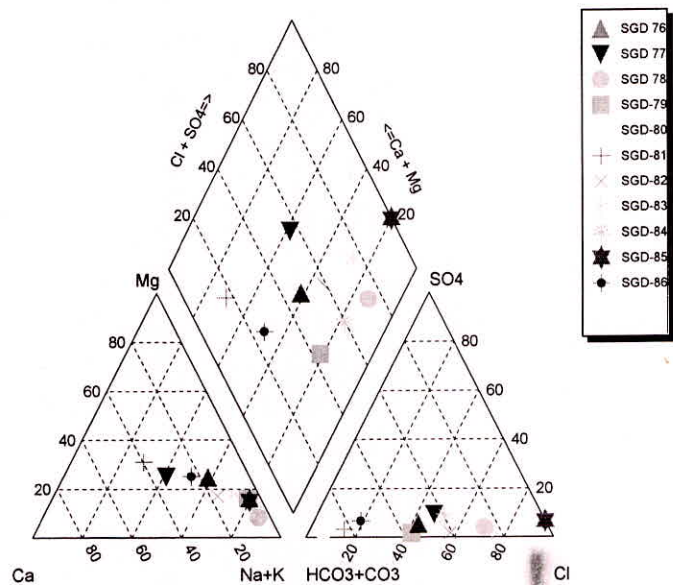
HP	SGD 59	Na-Ca-HCO ₃ -Cl
HP	SGD 60	Na-HCO ₃ -Cl
HP	SGD 61	Na-Mg-HCO ₃ -Cl
HP	SGD 62	Na-Cl-HCO ₃
HP	SGD 63	Na-Mg-HCO ₃ -Cl
HP	SGD 64	Na-HCO ₃ -Cl
HP	SGD 65	Na-Mg-HCO ₃ -Cl
HP	SGD 66	Na-Ca-Mg-HCO ₃ -Cl
HP	SGD 67	Na-Ca-Cl-HCO ₃
HP	SGD 68	Na-Ca-HCO ₃
HP	SGD 69	Na-Ca-Mg-HCO ₃ -Cl
HP	SGD 70	Na-Ca-Mg-Cl-HCO ₃
HP	SGD 71	Na-Mg-HCO ₃ -Cl
HP	SGD 72	Na-Ca-HCO ₃
HP	SGD 73	Na-Ca-Mg-Cl
HP	SGD 74	Na-Ca-Mg-HCO ₃ -Cl
HP	SGD 75	Na-Ca-Cl
HP	SGD 76	Na-Mg-HCO ₃ -Cl
HP	SGD 77	Ca-Na-Mg-Cl-HCO ₃
HP	SGD 78	Na-Cl
HP	SGD 79	Na-HCO ₃ -Cl
HP	SGD 80	Na-Ca-HCO ₃
HP	SGD 81	Ca-Mg-Na-HCO ₃
HP	SGD 82	Na-Cl-HCO ₃
HP	SGD 83	Na-Cl
HP	SGD 84	Na-Cl-HCO ₃
HP	SGD 85	Na-Cl
HP	SGD 86	Na-HCO ₃ -Cl
HP	SGD 87	Na-SO ₄ -Cl
HP	SGD 88	Na-Mg-Ca-Cl
HP	SGD 89	Na-Mg-Cl
HP	SGD 90	Na-Cl

HP	SGD 91	Na-Mg-HCO ₃
HP	SGD 92	Na-Cl-HCO ₃
HP	SGD 93	Na-Cl
HP	SGD 94	Na-Mg-Cl
HP	SGD 95	Na-HCO ₃ -Cl
HP	SGD 96	Na-Ca-HCO ₃ -Cl
HP	SGD 97	Na-Cl-HCO ₃
HP	SGD 98	Na-Ca-Cl-SO ₄
HP	SGD 99	Na-Ca-Mg-Cl
HP	SGD 100	Na-Mg-Cl
HP	SGD 101	Na-Ca-HCO ₃ -Cl
HP	SGD 102	Na-Ca-Mg-HCO ₃ -Cl
HP	SGD 103	Na-Ca-Cl-HCO ₃
HP	SGD 104	Na-Ca-HCO ₃ -Cl
HP	SGD 105	Na-HCO ₃ -Cl
HP	SGD 106	Na-Cl
HP	SGD 107	Na-Cl

Figure 4.5. All the piper diagram given below has been divided into smaller sections to get a clear picture fresh zone, saline zone and mixed zone.







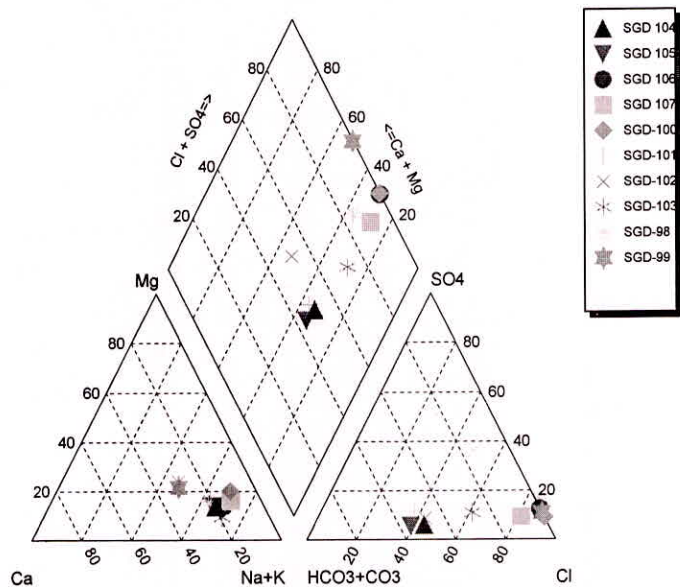
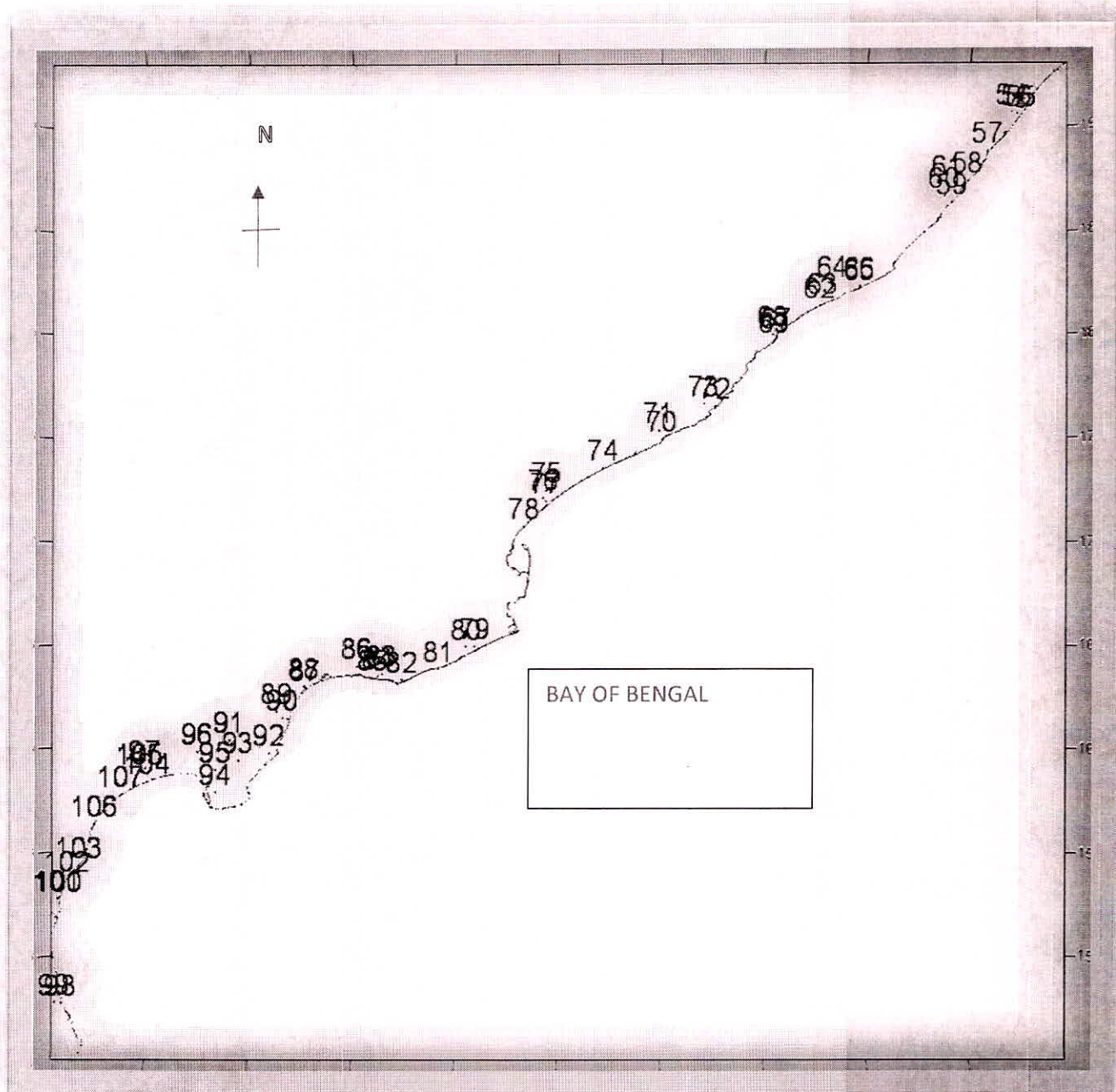


Figure 4.6. These are the points which come under fresh and saline zone.



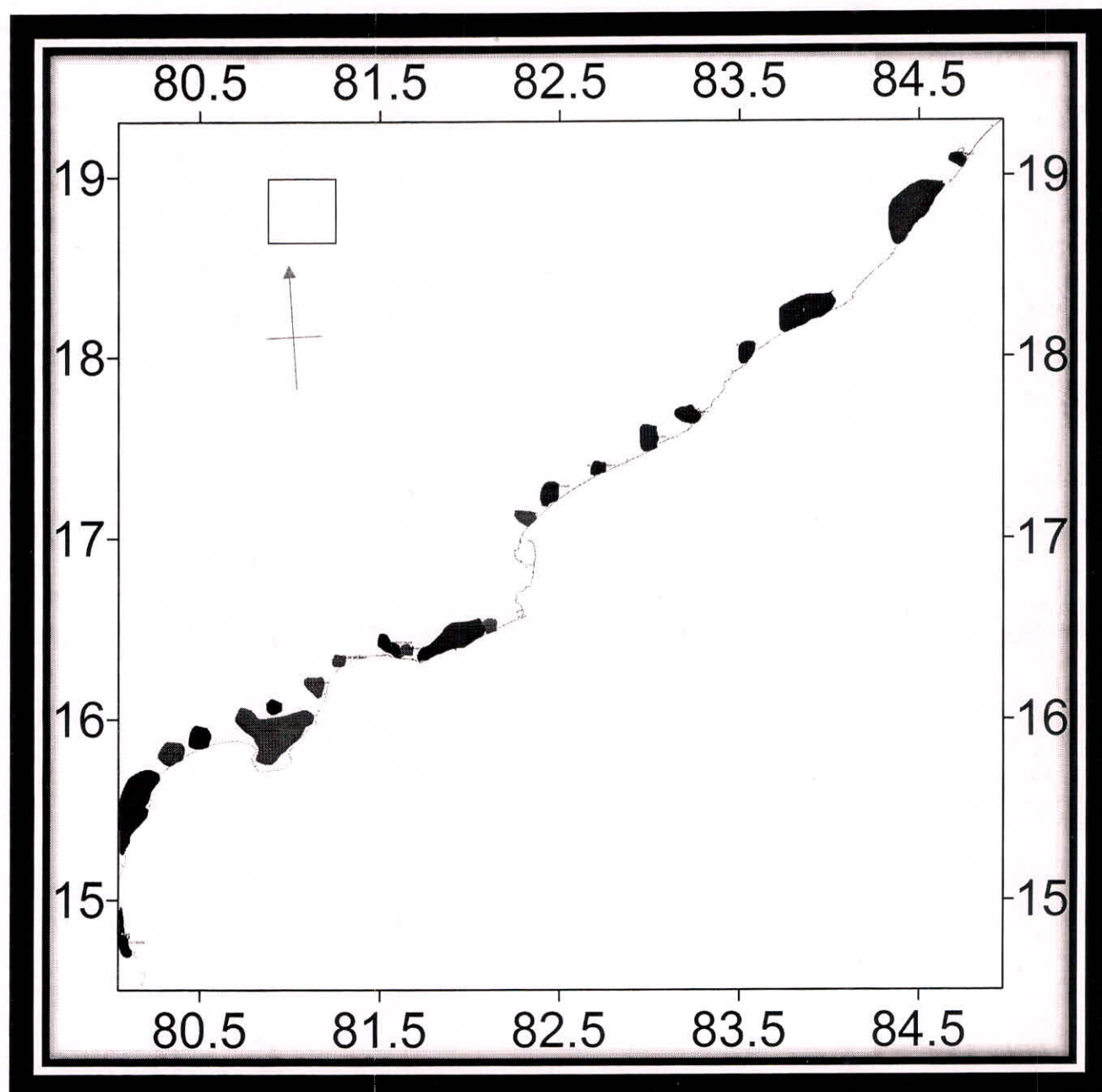


Figure 4.7. $\delta^{18}\text{O}$ and Chloride based seawater – groundwater interaction assessment.
(i) Groundwater is getting released into the marine environment from the blue marked zones
(ii) Along the red marked zone seawater is getting mixed into the groundwater
(iii) Groundwater at violet patches is saline mainly due to evaporation enrichment and due to leaching of salts.

Table 4.8: Preliminary criteria used to classify the hydrological process leading to groundwater salinity.

Water type	Indicator	Indicative colour
Fresh	$\delta^{18}\text{O} > -3\text{‰}$ & Cl<500	Blue
Evaporation enrichment + Salinity due to leaching of salts	$\delta^{18}\text{O} > -2$ to -1‰ & Cl 500- 1200	Purple
Possible intrusion of sea water	$\delta^{18}\text{O} > -1\text{‰}$ & Cl>1200	Red

CHAPTER 5

SUMMARY AND CONCLUSIONS:

GENERAL:

Groundwater is the most valuable and vital resource for sustenance of life and also for any developmental activity. Most of the coastal regions rely on groundwater as their main source of fresh water for domestic, industrial, and other activities. Coastal aquifers are increasingly threatened by sea water intrusion due to increased urbanization, groundwater exploitation and global sea-level rise.

Assessment is one of the initial step towards the remedial and control of sea water intrusion and hence the study shows the various relations of chemical and isotopic parameters to check the presence of SWI. The following section summarizes the salient features of the study and conclusion.

5.1. SUMMARY:

Assessment of the groundwater in the coastal zone is very much essential for the sustainability of the coastal living people who use to stay in the zones. The main aim of study is to assess whether the samples collected sites are suffering or going through salt water intrusion by the means of relation with chloride and O_{18} , through piper diagram and by ion balancing.

The study area has the coastal length of about 974km and sided by the Bay of Bengal. The coastal districts which are surrounded by the Bay of Bengal- Srikakulam, Vizianagaram, Vishakhapatnam, East Godavari, West Godavari, Krishna, Guntur, Prakasam and Nellore.

The samples are collected in the phase from North to South. And the sample collections are made in such a way that the every district status should be achieved.

The study involves the assessment of groundwater by means of isotopic and chemical changes. The early phase study depicts changes in EC of some places that is being provided by CGWB report. The EC is a one of the major parameter to indicate salt water intrusion. As ISI has given standards for drinking water desirable range 750($\mu\text{S}/\text{cm}$) and the minimum range got in this study is 490($\mu\text{S}/\text{cm}$).

Same as the chloride and O_{18} as we move away from coast O_{18} must increase and chloride value must decrease. All these values indicates the concentration of salts in the water it may be either through direct intrusion, or through evaporation or salinization in soil. The ion balancing is also important factor, there must be equal amount of cation and anion present in the sample to proceed the process. Imbalance concentration provides the error in the result.

The piper diagram is also being used to generate the diamond and its two subunits where the points lie if the ion concentration shows the type of water saline that place is getting intruded. And if the points lies in the fresh zone then fresh water is present in the area.

5.2. CONCLUSION:

Sea water intrusion represents a great risk to groundwater resources in coastal areas as it raises the levels exceeding acceptable drinking water standards. Sea water intrusion is a major problem in the coastal regions all over the world that should be controlled and the groundwater resources are to be protected from depletion. SWI can be controlled by firstly knowing the source from where it is coming and the reason of the intrusion. In this study the assessment of groundwater is done to detect the presence of salt water in coastal zones of Andhra Pradesh.

- Preliminary analysis gives the EC, pH, radon and temperature of the sample. And this data gives information about that the SGD 79 has crossed the desirable limit 750($\mu\text{S}/\text{cm}$) to 8400($\mu\text{S}/\text{cm}$) and the place is East Godavari.

- And while calculating the ion balancing the samples which are not having all ions are gets rejected for further process because that will provide error to the calculation and the error received in the data is about 5.916%.
- After plotting the piper diagram it is clear that the fresh water containing zone lies in the site id of SDG 58,78,72,81,91 and the places where it belongs are Srikakulam(akkupalli), Vizianagaram (kongavanipalem), Vishakhapatnam (agrigold beach), East Godavari (Karavaka), Krishna (pulligada).
- And SGD containing mixed zone are 56, 57, 58, 59, 60, 61, 62, 63, 64, ,66 ,67 ,69 ,70 , 71,74, 76, 77, 78, 79, 80, 82, 83, 84, 86, 88, 92, 95, 96, 97, 98, 101, 102, 103, 104, 105.
- And the main zone which is getting affected are SGD 55 Srikakulam (donkuru beach), SGD 73 Vishakhapatnam (pedagantayada), SGD 75 East Godavari (Thondandi road), SGD 85 West Godavari (perupalem beach), SGD 87 West Godavari (G.peddapatnam), SGD 88 West Godavari (Peddapatnam), and SGD 89 West Godavari (thatichetlapalem).
- SGD 93 Krishna (chodavaram) SGD 94 Guntur (lankevanidibba cyclone centre), SGD 99, 100 is in Prakasam, SGD 106,107 is in Nellore.

5.3. SPECIFIC CONTRIBUTIONS OF THE PRESENT WORK:

1. This study includes all the coastal districts together in a single work.
2. The results will be very much useful to identify the affected packets of the study area.

5.4. LIMITATION OF THE PRESENT WORK:

1. The samples collected from a single district is little less, if more samples will be there then the more variation of results will be shown.
2. And due to ion balancing the error if found is about 5.916% which is more than 5 which is not good.

5.5. FUTURE DIRECTION OF WORK:

- In future the different plots of can be made for irrigation purpose as SAR.
- The plots of the summation of chlorine, potassium and calcium by the EC, will give a standard results as same as BEX.

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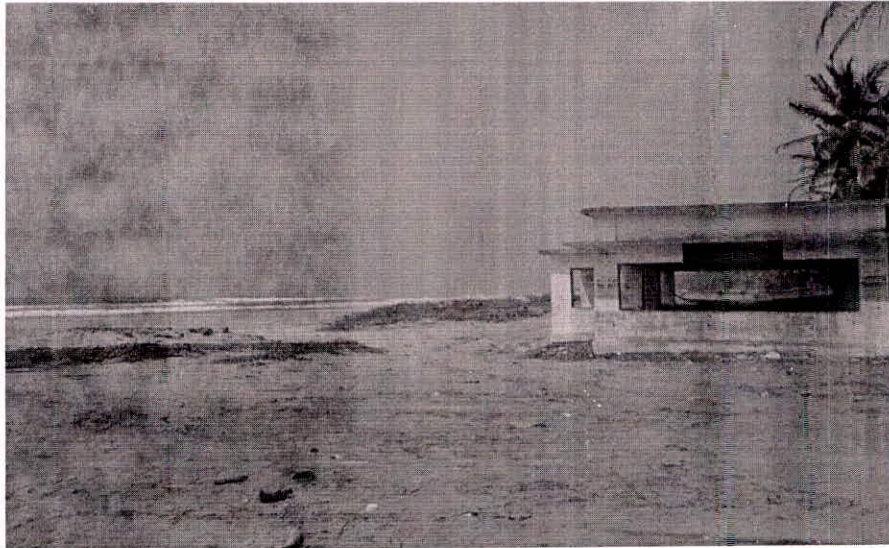


Figure.1.SHIVASAGAR BEACH (SGD 58)



Figure. 2. KR PETA (SGD 59)



Figure.3.PUNDI (T-Junction, Naupada-Palasa rd.)- SGD 60



Figure.4. KUNDUVANIPETA BEACH SGD(65)